FEB 2 1931

Heating · Piping and Air Conditioning

IN THIS ISSUE

Articles on

Heating—
By J. W. CARROW *and*
T. H. MONAGHAN

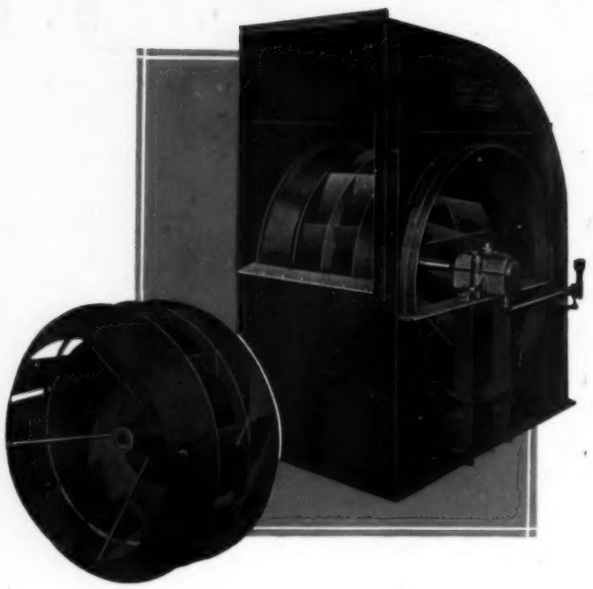
Piping—
By J. J. HARMAN *and*
B. M. CONATY

Air Conditioning—
By RALPH E. PHILLIPS *and*
MALCOLM TOMLINSON

Journal Section
of A. S. H. V. E.

FEBRUARY, 1931

CLARAGE



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The EDITOR'S PAGE

Heating · Piping and Air Conditioning

FROM ARTICLES IN THIS ISSUE

"It has been found . . . that . . . air cooled offices make the rental problem an easy one and allowed the building to demand rentals which are among the highest in the city."—*Ralph E. Phillips.*

"In industrial plants and institutions the desire for metering steam consumption exists but is not always satisfied due, perhaps, to a lack of information on the use of meters."—*B. M. Conaty.*

"It is therefore seen that by operating at two hydraulic pressures, often a saving can be effected which is worthwhile a factor in any plant."—*F. G. Schranz and W. L. DeLaney.*

"With intelligent automatic control of this sort it is possible to obtain advantage of the cooling powers of the relative humidity."—*Malcolm Tomlinson.*

"The Cleveland Terminal . . . embodies many departures from general practice in passenger terminal design."—*J. W. Carrow.*

"In the present state of knowledge regarding the performance of metals in long continued services at temperatures around 1,000 F and higher, a new and important duty devolves upon the maintenance man, and that is to keep careful watch of the various elements of the piping system and make sure that no abnormal creep is taking place."—*J. J. Harman.*

"At first sight it may appear strange that refrigerating machines can be used for heating purposes, yet the idea was put forth by Lord Kelvin in 1852."—*H. J. Macintire.*

"As with other types of sterilizers, the capacities of water sterilizers are debatable, depending upon the economical use of sterilized water, but the following minimum sizes, the writer believes, are the general consensus of opinion."—*Rollo E. Gilmore.*

"Plant conditions required a change in a pipe coil which was, for the most part, obstructed by the steel supports of a storage rack, containing heavy steel dies and machine parts. The work was done in the following manner . . . "—*W. H. Wilson.*

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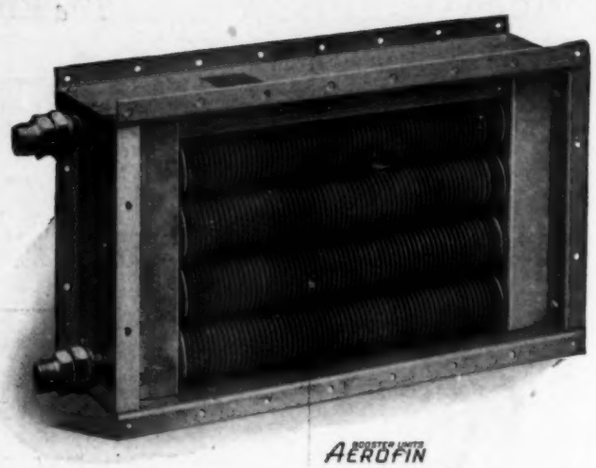

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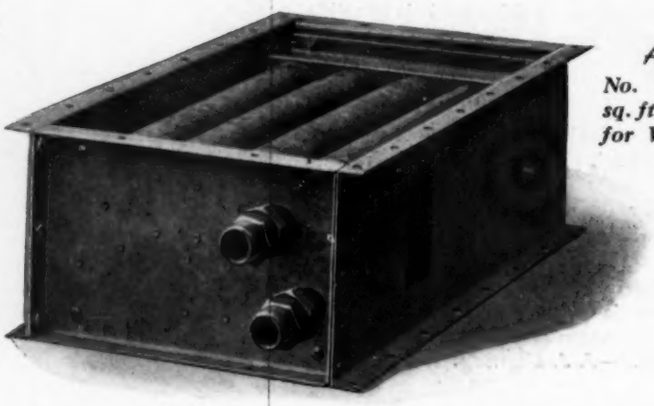

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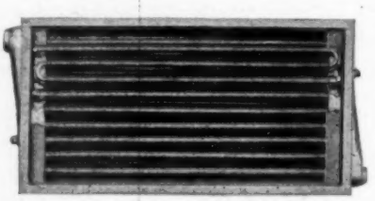

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TABLE OF CONTENTS

FEBRUARY, 1931

	Page
HEATING AND AIR CONDITIONING THE CLEVELAND UNION TERMINAL *By J. W. Carrow*	99
HIGHER PRESSURES AND TEMPERATURES AS THEY AFFECT THE DESIGN, INSTALLATION AND MAINTENANCE OF PIPING *By J. J. Harman*	106
CONTROLLED COOLING IS PROFITABLE *By Malcolm Tomlinson*	113
COAL AND ASH HANDLING FOR BOILERS FIFTY FEET UNDER CHICAGO RIVER *By T. H. Monaghan*	116
SELECTING STERILIZERS *By Rollo E. Gilmore*	119
OFFICE BUILDING RENTAL PROBLEM SIMPLIFIED BY AIR CONDITIONING SYSTEM *By Ralph E. Phillips*	124
USE OF CONDENSATION METERS IN HEATING SYSTEMS *By B. M. Conaty*	130
REFRIGERATORS FOR HEATING	132
HOW TO FIGURE AMOUNT OF WATER USED BY HYDRAULIC PRESSES *By F. G. Schranz and W. L. DeLaney*	135
"OPEN FOR DISCUSSION"	137
EDITORIALS	183
SOME REPORTS ON RESEARCH	185
PRACTICAL PIPING PROBLEMS *By W. H. Wilson*	187
ADVERTISERS' INDEX (Advertising Section)	164

JOURNAL SECTION OF A. S. H. V. E.

Heat Emission from the Surfaces of Cast Iron and Copper Cylinders Heated with Low Pressure Steam, by A. C. Willard and A. P. Kratz	141
Smoke and Dust Abatement, by Melvin D. Engle	146
Air Conditioning in the Bakery, by W. L. Fleisher	158
Heating Effect of Radiators, by R. V. Frost	168
Utilization of Hot Springs for Heating in Iceland, by Ben Gröndal	174
Bulletin Section	179

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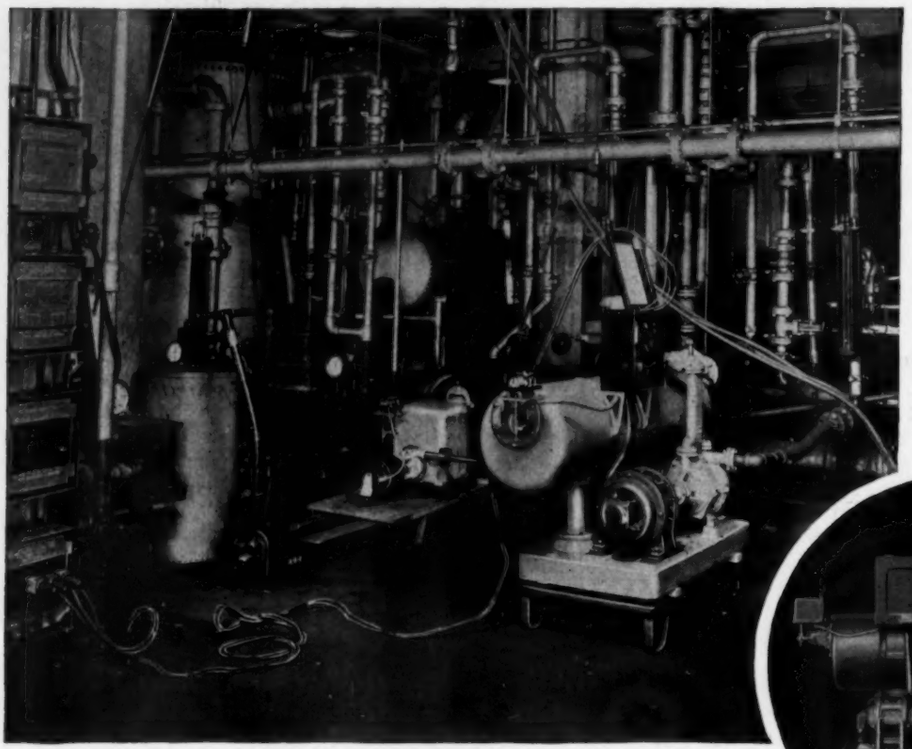

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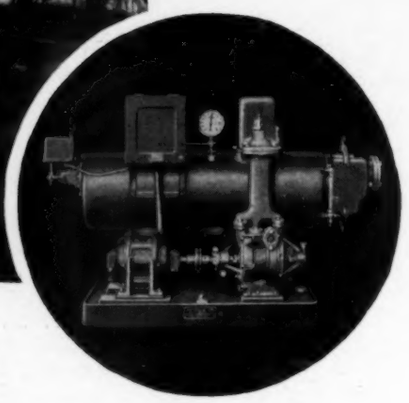

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Heating · Piping and Air Conditioning

Vol. III *February, 1931* **No. 2**

Heating and Air Conditioning the Cleveland Union Terminal

By J. W. Carrow*

ABOVE—A VIEW OF THE ENTRANCE PORTICO

A STRIKING NIGHT VIEW OF THE MAGNIFICENT CLEVELAND TERMINAL, DEDICATED IN 1930

CLEVELAND'S new union station (owned and operated by the Cleveland Union Terminals Company) faces the public square. It was formally dedicated June 28, 1930, and embodies many departures from general practice in passenger terminal design. From the street one hardly realizes the size of this magnificent railroad station, which lies entirely below the street level.

The station facilities, concourses, ticket lobby, waiting room, cab stand, baggage and parcel rooms are located on main floor at elevation 72.5 or 12.5 ft. below the main entrance from the public square. All of the concession spaces, including the lunch room, dining room, drug store, food shop and barber shop, are located on this floor and are operated by Harvey, Inc.

The track platforms, at elevation 52.67 or 19.83 ft. below the 72.5 level, extend

THE STEAM CONCOURSE FROM THE TICKET LOBBY

* Mechanical department, Graham, Anderson, Probst, and White, architects, Chicago.

under the entire main station floor. The 85.0 level, 12.5 ft. above the 72.5 level floor and occupying portions of the entire level, is devoted to station facilities and mechanical equipment. The cross-sections on p. 103 bring out very clearly the relation of street levels to the different floors. In conformity with the carefully worked out plan, a massed group of air right structures has been built over portions of the area; provisions have been made for future buildings over the remainder of the station area above the 85.0 level.

Steam Piped ¼ Mile

Steam for all heating purposes is obtained from the Cleveland Electric Illuminating Co., located about one-quarter of a mile south of the station. It is piped from the power plant to the center of the station in Canal Road and is extended further in a concrete tunnel north below the tracks to the public square and Ontario street, supplying steam to other buildings in this vicinity. Steam for the station is taken directly from the tunnel through track level story into the pump room, 72.5 level, and distributed to all points of service.

In general the heat losses for the entire station are through the floor and roof, the outside exposed wall surface being very small.

Forced Hot Water System Used

The nature of the building necessitated using a forced circulation hot water system, because the condensate return from a steam system would have been exposed at the track level ceiling, and as this story is unheated it was not possible to adequately protect piping against freezing. To minimize the radiation of heat through the floor, one-in. cork insulation was placed directly on the rough slab and beneath the floor fill for the entire 72.5 level floor heated areas.

Steam radiation is installed in the skylights of the concourse without impairing the natural light. Main thoroughfare streets and cross streets pass directly over the ticket lobby and concourses. Pipe coils heated by steam are placed in the street construction; they serve the double purpose of decreasing the radiator sizes in 72.5 level and eliminating dampness in the street construction, thereby preventing steel corrosion. Still another heating problem presented itself in the track level story—preventing the cold water mains supplying fire hydrants in the street level from freezing. High pressure steam is used for this purpose, controlled from the tunnel and turned on only when the outside temperature is 32 F or below.

The Air Conditioning

The entire station, being below the street level and almost without outside light (it has only fifty-four outside windows) necessitated mechanical ventilation throughout the area. The lunch room, dining room, and barber shop are provided with cool air during the warm summer months. A canopy constructed of corrugated sheet asbestos and provided with a spray of water over its roof, is built over the fresh air intake of the ventilating units not equipped with cooling, to reduce the temperature of the inside rooms below the outside temperature. The total ventilation installation includes sixty-one fans with an ultimate of sixty-five, the largest individual fan capacity being 85,000 cubic feet of air per minute and the smallest 250 cubic feet of air per minute.

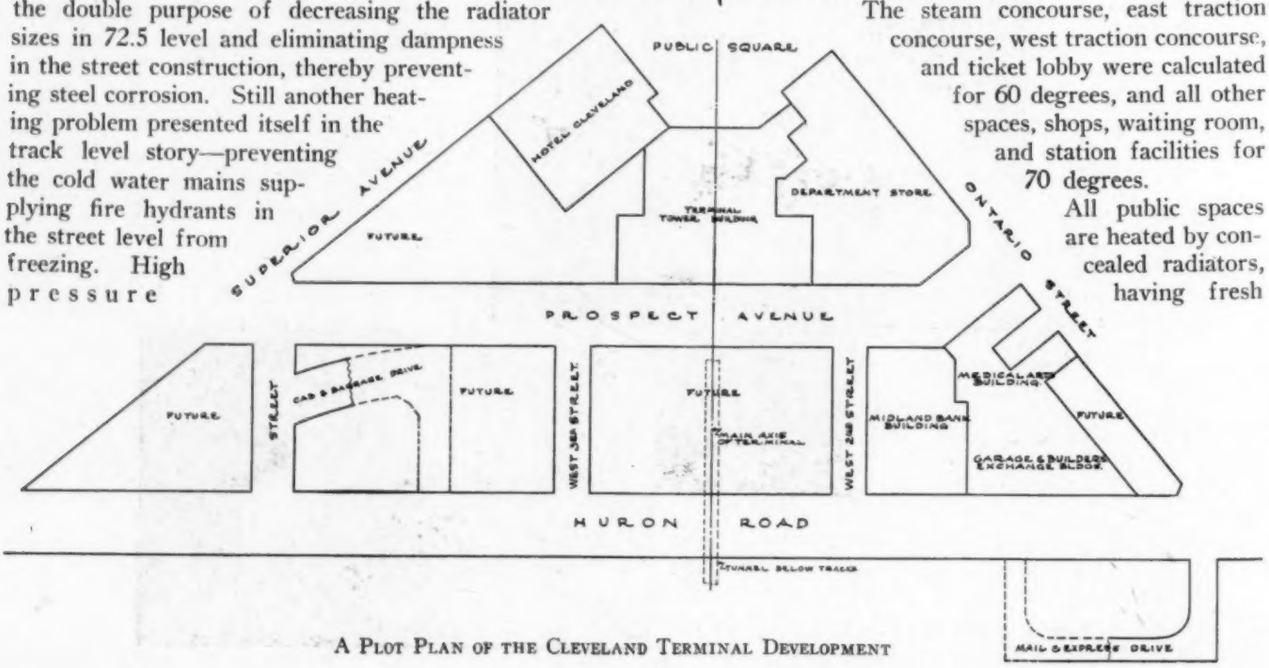
All trains are hauled through the station by electric-driven locomotives. The track level story is entirely enclosed by retaining walls, except the south side, which is open for its entire length. Ventilation in this story is by natural circulation through shafts extending from track level ceiling to roofs above. Each shaft has an area of 22 square feet, based on one square foot of shaft area to each 1,800 square feet of covered track space. They are installed at different locations over the entire area.

Editor's Note: In the second part of this article, to be published next month, the ventilation of the station and the air conditioning systems for the dining room, the lunch room and the barber shop are described in detail.

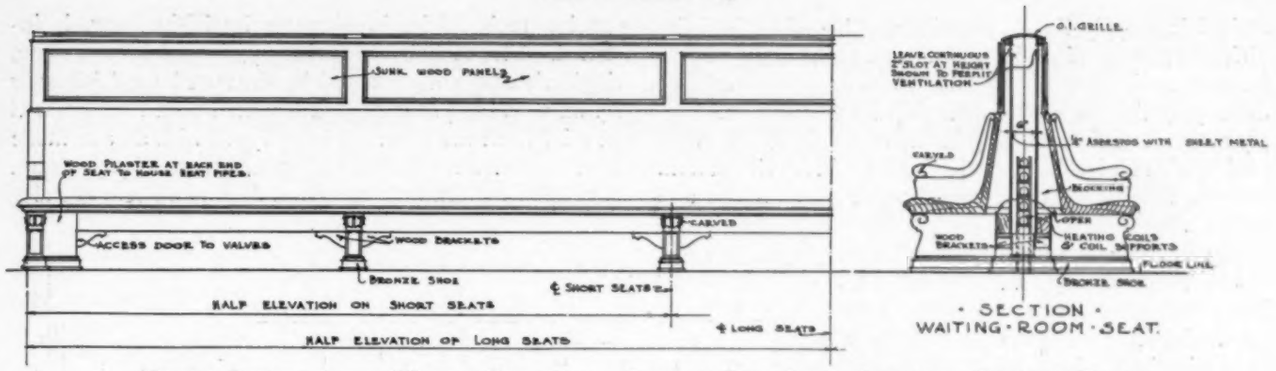
The Heating Systems

All portions of the 72.5 and 85.0 levels are heated by forced circulation hot water except the toilets, baggage room, mail and express facilities and cab stand vestibule. The heating of these rooms is accomplished by an indirect system, warm air being supplied at the ceiling at a temperature averaging about 85 degrees, to maintain 60 degrees within the rooms. The steam concourse, east traction concourse, west traction concourse, and ticket lobby were calculated for 60 degrees, and all other spaces, shops, waiting room, and station facilities for 70 degrees.

All public spaces are heated by concealed radiators, having fresh



A Plot Plan of the Cleveland Terminal Development



Typical Details of the Waiting Room Seats, Showing How Air Is Introduced Through Them

air supplied by ventilating fans through the radiator and enclosure, to increase the efficiency of the radiation. The enclosures are all located at the floor directly above the base board and are furnished with hinged grilles for access to the radiators.

Twelve columns through the center of the ticket lobby in a north and south direction are supplied with 38-in., 4-tube, 17 sq. ft. radiators, without legs, at each face, and hung on the structural columns. Radiators, piping and duct work are confined within a square architectural column 3 ft. 6 in. overall.

At the exterior walls radiators are located at the different intervals most suitable architecturally. In the east traction concourse and west traction concourse, radiators are along the exterior walls, at the head of stairs and at the stair landing midway between the track level and 72.5 level. The steam concourse is treated in a similar way, except 1½-in. pipe coils heated by steam are placed in the space above ceiling lights, supported on trusses to compensate for roof and skylight losses. In the waiting room the seats are placed back to back with a small space between, in which are placed U bend 1½-in. pipe coils; natural circulation is provided through the coils by the air which flows inward below the seats and out through grilles above the coils, as shown above. For the entire 162-ft. length of the waiting room there are eleven pipe coil radiators. All shop spaces have concealed radiation with both natural and forced air circulation through the radiators. Other spaces throughout the station are heated by exposed radiation, wall hung and floor type.

Heat Loss Factors

Heat loss factors used were 0.12 Btu for floor, 0.24 Btu for wall, 1.00 Btu for glass per square foot and .02 per cubic foot of contents per degree per hour. Where hot water was used as the heating medium, 180 Btu per square foot of heating surface per hour, and where steam was used, 250 Btu per square foot of heating surface per hour were used as the basis for determining the amount of radiation.

Hot Water Converters

Two hot water converters, each having the full capacity of the system, heating the water to 195 degrees for 27,000 square feet of radiation and supplied with steam at atmospheric pressure through an 8-in. steam line, supply the hot water heating system. They are closed type heaters, with ⅜-in. thick steel shells and seamless copper tubes. Automatic temperature regulation and thermometers are provided for each converter. Heaters are so valved that one or both can be used as desired.

Circulating Pumps

Hot water is circulated through the entire system by two 450 g.p.m. centrifugal pumps operating at a frictional head of 50 feet. Each pump is full capacity of the system and direct-connected to a 10 hp., 1,750 r.p.m., 230 volt, direct current, constant speed motor. Pumps have a 4-in. suction and 3-in. discharge and are valved so that one or both pumps may operate as required.

Pump suction is taken from the return lines and discharged through the converters into a 6-in. main supply for the entire building. For the purpose of balancing the load, the building was divided into two zones (namely, east of the main axis and west of the main axis) and fed by two 5-in. lines from the main 6-in. hot water heating supply in the pump room. From these

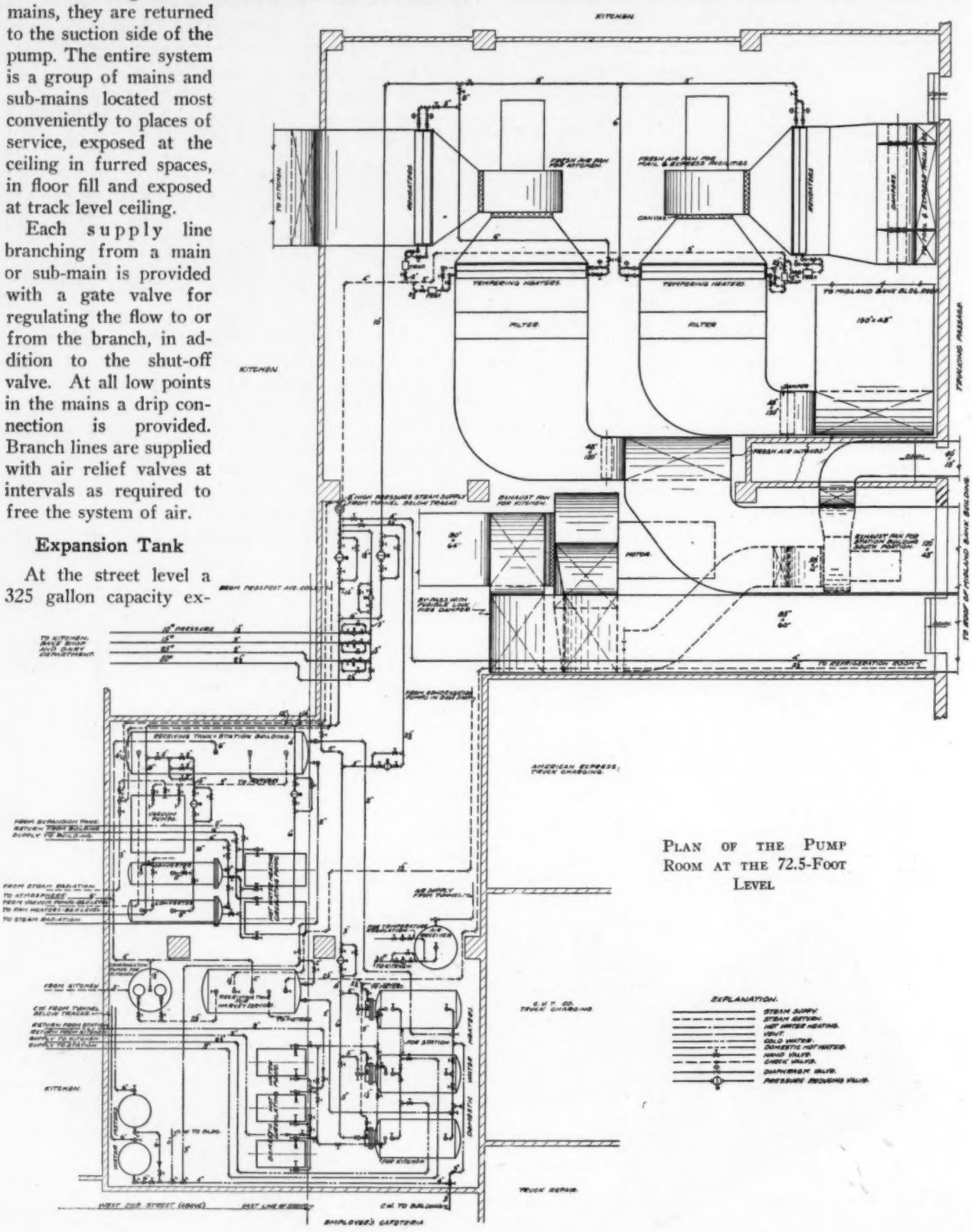
Three of the Sixty-one Fans Included in the Ventilating System. Individual Fan Capacities Range From 85,000 to 250 C.F.M.

main 5-in. supply lines, submains and branches feed the different groups of radiators. At the point of first service to a radiator a return line commences and parallels the supply line the entire distance, the water in the supply and return lines flowing in the same direction, which avoids short circuiting and gives positive circulation. After collecting all the return branches, sub-mains and mains, they are returned to the suction side of the pump. The entire system is a group of mains and sub-mains located most conveniently to places of service, exposed at the ceiling in furred spaces, in floor fill and exposed at track level ceiling.

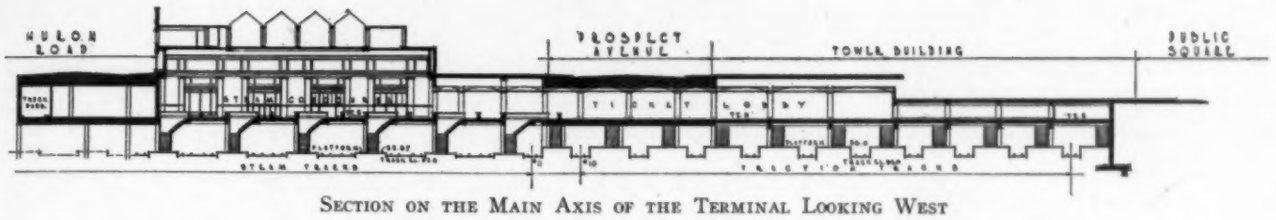
Each supply line branching from a main or sub-main is provided with a gate valve for regulating the flow to or from the branch, in addition to the shut-off valve. At all low points in the mains a drip connection is provided. Branch lines are supplied with air relief valves at intervals as required to free the system of air.

Expansion Tank

At the street level a 325 gallon capacity expansion tank, 36-in. in diameter by 72-in. long, is installed. The tank is cylindrical, 3/8-in. thick steel plate, single riveted, with bumped beads, tested for 75 lb. per sq. in. working pressure, and is placed on a foundation 2 ft. 6 in. from the floor. It is equipped with an automatic float control valve for cold water make-up, city pressure. A manhole, overflow, gage glass, drain, and vent are also



PLAN OF THE PUMP ROOM AT THE 72.5-FOOT LEVEL



SECTION ON THE MAIN AXIS OF THE TERMINAL LOOKING WEST

provided in addition to the 2-in. expansion line from the bottom of the tank returning to the pump room and connecting to the suction line near the pumps. Expansion of the water in the system is cared for through an overflow to the sewer in the top of the tank, the vent being installed to prevent syphoning of water.

Steam Services

The pump room in the 72.5 level, the central point of service, is supplied with steam from the tunnel below the tracks at 125 lb. through an 8-in. pipe, a total maximum load of 1,125 lb. per minute at 11,500 f.p.m. velocity. An intermediate pressure reducing valve in the main header reduces the steam pressure to 30 lb. From this point the different services are supplied, each having its individual reducing valve, the pressure varying from 15 to 0 lb. Each pressure reducing valve is valved on each side, with a valved by-pass and a steam gage on the low pressure side of the reducing valve.

Pressures for Concessions

Steam for the Harvey, Inc., kitchen, bake shop, and dairy department is supplied by an intermediate reducing valve set at 50 lb.; a total demand of 1,500 lb. of steam per minute was estimated for these services. A reducing valve is furnished for each of the different pressures below 50 lb. The following are the steam pressures required for this equipment:

Kitchen—72.5 level.

10 pounds—Compartment steamers and coffee urns.
15 pounds—Silver, dish and glass washers and egg boilers.
25 pounds—Steam tables, bain Marie pans, plate heaters, and small kettles.
50 pounds—Large kettles.

Bakery—72.5 level.

10 pounds—Compartment steamers.
35 pounds—Large kettles.

Dairy Department—85.0 level.

30 pounds—Sterilizing and cleaning equipment.

Each piece of equipment requiring a steam return is provided with a steam trap and check valve; the check valve is located between the fixture and the trap. All fixtures have a hand control valve conveniently located in the supply and return line at the fixture. Return lines are in the floor fill and return by gravity to condensation pumps, steam supply being located in the furred ceiling above the fixture.

High Pressure Steam for Refrigerating Plant

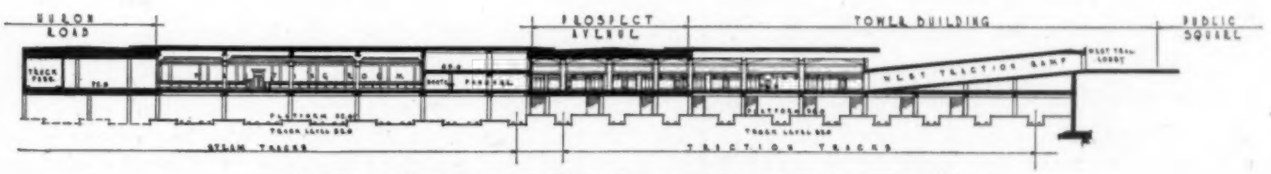
A 4-in. high pressure 125-lb. main furnishes the steam supply for the 175-ton absorption refrigerating plant located east of the joint drive and on the 72.5 level. A maximum demand of 10,500 pounds of steam per minute is required for this plant. High pressure steam is used to operate the ammonia pumps and low pressure for the generating units of the refrigerating system. All exhaust steam from the ammonia pumps is used in the generators, the additional make-up for the generators being obtained through the intermediate and low pressure reducing valves, the low pressure valve operating at 5 lb. gage.

Two-Pipe Vacuum System Heats Part of Terminal

The Pullman quarters at the street level of Huron Road, the pent house, and the void space above the steam concourse ceiling, are heated through a two pipe up-feed vacuum system. Steam is supplied to these spaces through a low pressure reducing valve in the pump room and controlled from this point. The condensation from these spaces is returned to the header at the vacuum pumps in the pump room. Cast iron tube radiation and 1½-in. pipe coils were used in these spaces. A total of 4,448 square feet of direct radiation was installed.

Prospect avenue from the east wall of the bake shop to the east wall of the cab stand, west Second street for its entire length, and Huron Road east of the main axis to a line with the east wall of the steam concourse and west of the main axis to a line with the west wall of the waiting room, is also heated through a two-pipe vacuum system. The entire radiation consists of groups of 2-in. brass pipe coils not over 140 feet long, connected at each end to a 2½-in. header, the steam supply header being located at the high point of the street, the coils pitching with the street construction and parallel with the street. Prospect avenue is provided with four separate groups of coils, west Second street with two groups and Huron Road, two groups. Individual hand shut-off valves and steam return traps in accessible locations below the cement tile ceiling under street construction were installed for each group of coils. Steam supply is controlled at the pump room; condensation is returned to vacuum pumps in this room.

Fan heaters located in the 72.5 level pump room, 85.0 level and pent house and totalling 27,950 sq. ft. of heating surface are also supplied by a two-pipe vacuum sys-

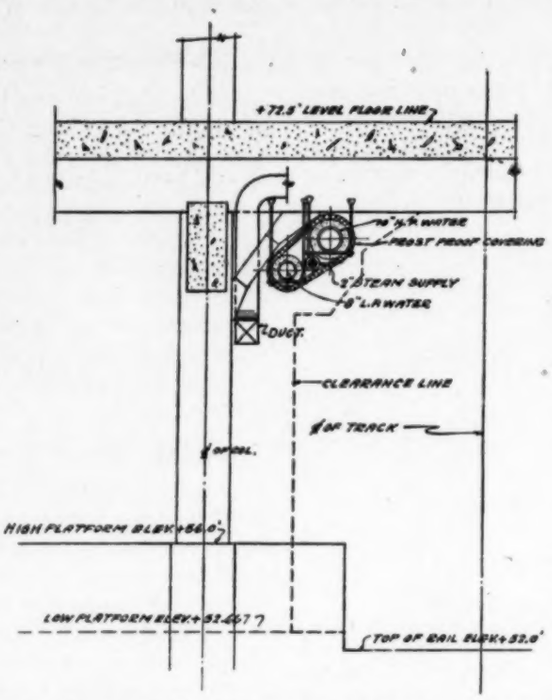


A SECTION THROUGH THE WEST TRACTION CONCOURSE, LOOKING WEST

tem. Steam for fan heaters totalling 7,100 sq. ft. in the third story of the Tower building is obtained from the Tower building service, the station building operating its own vacuum pumps for this group of heaters.

Preventing Fire Mains from Freezing

At the track level ceiling over platforms below Prospect avenue and Huron Road, and parallel with the street, are two cold water fire mains, an 8-in. low pressure and a 10-in. high pressure. These extend for a distance of 450 feet under each street and are heated by high pressure steam supplied from the tunnel. Hand-control valves in the steam supply lines are located in the tunnel. These cold water lines supply fire hydrants at the street level, are entirely without circulation and could not be adequately covered as protection against freezing. This protection was obtained by the installation of a bare high pressure steam pipe parallel and adjacent to the water mains. In space throughout the track level, in unheated spaces above the track level and in fire hydrant pits, the water lines are covered with 1-in. thick felt covering. Water and steam pipes are encased in a 1-in. hair felt casing and finished with tar paper. Gravity return steam traps were installed at all low points, discharging condensation to the sewer. Steam is supplied to these mains only when the outside temperature drops to 32 F.



This Sectional View Shows the Method of Heating the Fire Lines Where They Are Exposed in the Track Spaces

Domestic Water Heaters

Three U-tube closed type water heaters 48-in. in diameter by 108-in. long, storage capacity 800 gallons, and a heating capacity of 2,000 gallons of water per hour from 50 degrees to 180 F, with steam at zero lb., furnish the hot water supply. Two heaters are for the station and the third for the Harvey kitchen and bake shop services. The heaters are cross-connected so that two heaters can be used for the kitchen and bake shop service if necessary. Each unit is constructed of ½-in. flange steel with No. 16 gage 1¼-in. diameter copper tubes, connected to a single header. Accessories provided are relief valves, thermometers and automatic temperature regulation. The heaters rest on steel saddles on concrete piers 4 ft. from the floor to the bottom of the tanks, steam traps and condensation meters being placed directly below. The cold water supply to the heaters is passed through coils in the separating and receiving tanks, thereby tempering the water.

Domestic Hot Water Circulating Pumps

A centrifugal pump is installed for each heater, having a capacity of 50 gallons per minute against a frictional head of 70 ft. and direct connected to a 5 hp., 230 volt 1750 r.p.m. motor. Pumps are connected to the heaters and circulating system to insure positive circulation.

Receiving Tanks

There are two receiving tanks in the 72.5 level pump room, one used for the station building and the second for Harvey Inc. services. Each tank is equipped with separate condensation meters.

The tank used for the station building service is 48-in. in diameter by 16-ft. long set horizontally, having a capacity of 1,500 gallons and constructed of ¼-in. steel tested to 75 lb. per sq. in. working pressure. Condensation from all fan heaters, steam radiation and steam coils in streets, is delivered to this tank.

Condensation from water heaters and converters is discharged directly to the sewer from steam traps. Two-in. pipe coils are placed at the bottom of the tank for its entire length, the cold water supply to the domestic water heaters flowing through these coils, tempering the supply and reducing the temperature of the condensation to about 90 degrees before it passes to the meters and discharges to the sewer. The returns enter the top and leave through an opening in the bottom of the tank. Piping connections to the tank are so arranged that at all times the receiver is not less than one-half full of condensation, the length of time it remains in the tank depending on the steam demand.

A 6-in. vent to the atmosphere, terminating with an exhaust head, relieves the pressure within the tank and provides a steady flow of condensation to the meters. A gage glass for determining the water level and a manhole are also provided. The tank rests on steel supports 2 ft. 6-in. above floor with space for condensation meters directly below.

The receiving tank for the Harvey services is constructed similar to the one for the station building. This unit is 48-in. in diameter by 96 in. long, having a capacity of 750 gallons and receiving condensation from the kitchen, bake shop and refrigerating plant condensation return pumps.

Radiators

The radiation furnished is of cast iron exposed and concealed, of water pattern type with plain surfaces. Each unit is tapped at the top for the supply and at the bottom (opposite end) for the return. The supply end of each hot water radiator is equipped with a graduated dial adjustable opening valve and on the return end with a railroad union. Each steam radiator has a hand control supply valve and a return trap. Concealed radiators

FRESH AIR FOR THE TAXI CAB STAND WAS FIGURED AT 5000 C.F.M. PER CAR. AIR IS SUPPLIED FROM THE TRACK LEVEL, SUPPLEMENTED BY THE AIR THROUGH THE DRIVE ENTRANCES

are hot water and are manually operated through hinged grilles or small hand holes in grilles. Supply and return connections to hot water radiators are ½-in., with the supply valve full size of the connection. Standard weight wrought iron pipe coils are used for hot water heating in the waiting room and steam heating in the steam concourse skylights. All steam street heating is supplied by 2-in. extra heavy brass pipe.

Sizes of connections to steam radiators and coils are as follows:

Up to 60 sq. ft.— ¾ in. supply and ¾ in. return.
60 to 90 sq. ft.—1 in. supply and ¾ in. return.
90 to 140 sq. ft.—1¼ in. supply and ¾ in. return.
140 sq. ft. and larger—1¼ in. supply and ¾ in. return.

No supply is made smaller than ¾-in., supply valves full size of radiator and coil connections; return valves for 60 sq. ft. and smaller are ½-in. and, above, ¾-in.

Vacuum and Condensation Pumps

Return line duplex centrifugal vacuum heating pumps were selected. The pumps are direct connected to 230 volt, d-c, 1800 rpm motors. Each pump is full capacity of the system served, automatic and suitable for a vacuum of 20 inches of mercury if desired.

The refrigeration plant in the 72.5 level is provided with duplex condensation pumps; the capacity of each pump is 35 g.p.m. at a discharge pressure of 30 pounds, direct connected to a 1½ hp., 230 v. d-c 1800 rpm motor.

Duplex vertical type centrifugal condensation pumps, with a receiver 42 in. in diameter by 36 in. deep (each pump having a capacity of 10 g.p.m., direct connected to a ¾ hp. 220 v. d-c 1,720 rpm motor operated by a float switch) are installed in the bake shop and in the 72.5 level pump room. The receiver and pumps are placed below the floor in a concrete enclosure suspended from the 72.5 level floor construction and lined on the inside with 1-in. cork as protection against freezing. The condensation return lines are located in the raised floors and flow by gravity to the receiver from the kitchen and bake shop fixtures.

Piping throughout the building is run exposed, in furred ceilings and in floor fill. Supply and return piping for radiators is installed for short distances in inverted "U" shaped covers of No. 20 gage galvanized iron concealed in the floor fill above the beams. In the bake shop and main kitchen (72.5 level) the normal floor is raised 5 inches, the floor construction consisting of 8 inches of tile laid solidly on the top of the rough concrete slab and finished with 2½ inches of base and finished flooring. This provides space for hot and cold water, vent, waste, steam return, and brine pipes.

Expansion in general is taken care of by swing joints. Where it was impossible to care for it in this manner, internally guided type expansion joints were used, constructed of brass for sizes 2 inches and smaller and 2½ inches and larger having iron bodies and brass sleeves. Expansion joints were installed in the street construction to take care of the street movement due to change in temperature. All plumbing and heating pipes crossing these joints are provided with expansion joints where it was impossible to install swing joints.

Main steam supply and return pipes are pitched not less than ¼ in. in 10 ft. and all small piping not less than 1-in. in 10 ft. Hot water supply and return mains are run level.

Foundations

All machinery is erected on framed floors; it was very essential that all machine rooms be noiseless as they are located adjacent to public spaces. Concrete foundations for all centrifugal pumps rest on a 2-inch layer of machinery cork on top of the rough slab. Ammonia reciprocating pumps are slow speed type; foundations are constructed similar to those for centrifugal pumps. Fan and motor bases are bolted to 6 by 4 in. dressed yellow pine frames with a layer of ⅜-in. thick compressed cork between the base and pine frame and another layer directly under the frame. Two by two in. angles are fastened securely to the four sides of the frame and are covered by floor fill. An anti-vibration platform is constructed under the compressor and the motor of the refrigerating unit for the sandwich shop and service kitchen on the 72.5 level.

Higher Pressures and Temperatures as They Affect the Design, Installation and Maintenance of Piping

Article No. 3

By J. J. Harman*

In this article—the last of Mr. Harman's series on high pressures and temperatures as they affect piping—the author discusses alloys and heat treatment, valve trim materials, pipe joints, etc. He points out the increased responsibility the past ten years' boost in pressures and temperatures gives the piping engineer.

WHILE carbon steel has given an excellent account of itself in service at the pressures and temperatures now in common use, nevertheless the outlook for the future indicates a need of metals that are stronger at high temperatures and are better able to withstand the ravages of oxidation, which becomes much more active in the high temperature zone. Consequently, it is not surprising that the past few years have been marked by intensive research in the field of both ferrous and non-ferrous heat resistant and corrosion resistant alloys. Numerous alloy steels have been developed, some in the low alloy zone, which cost little more than plain carbon steel to produce, some in the intermediate alloy zone, which are more expensive, and a number in the high alloy zone, which are usually still higher in cost. Obviously the application of the more expensive alloys is limited to service conditions where the less expensive alloys can not be economically and safely employed, and while this economic limitation has prevented the widespread use of many of the new alloy steels, some of them are being used in considerable tonnages.

Of the alloying elements added to steel for the purpose of increasing its heat and corrosion resisting ability at high temperature, nickel and chromium apparently are the most extensively used at present. It has been stated that nickel increases resistance to oxidation, but does not increase load carrying ability at high temperature, also that added strength at high temperature can only be secured by substantial additions of the carbide-forming elements such as chromium, tungsten and molybdenum. This theory, however, has not been entirely substantiated by test data, as in some cases high temperature strength has actually been reduced by increasing the chromium addition beyond about 20 per cent. Silicon, titanium, vanadium, manganese and cobalt have also been used to advantage as alloying elements in conjunction with the elements previously mentioned.

The group of austenitic alloys (one containing 18 per cent chromium and 8 per cent nickel is an outstanding example) have excellent heat and corrosion resisting properties at high temperatures, and while they are being used to an increasing extent they have the economic disadvantage of a relatively high initial cost. The stainless irons of the 0.10 per cent carbon and 13 per cent chromium variety are not much stronger than the less expensive steels at temperatures above 1,000 F and are relatively high in cost, but their corrosion resisting properties are a great advantage in many instances and this steel is being extensively used.

In the intermediate alloy range a comparatively new steel containing from 4 to 6 per cent chromium with or without vanadium is worthy of note because it apparently is meeting certain oil refinery requirements satisfactorily and the cost is less than that of some of the high alloys. In the low alloy field may be mentioned a chrome-nickel cast steel containing approximately 0.40 per cent carbon, 0.70 per cent chromium and 1.75 per cent nickel, which has been rather extentively used in the oil industry at temperatures up to 1,100 F. The safe creep stress of this alloy is considerably higher than that of carbon steel at temperatures up to 1,000 F, but the curve slopes rapidly downward and reaches the carbon steel curve at about 1,100 F, so it appears to offer no advantage at higher temperatures. Much development work still remains to be done in the temperature zone above 1,000 F and this doubtless will extend over a period of years, because long test periods are required to definitely determine the operating characteristics of new alloys under the long continued action of high temperature.

The strength of all steels—and particularly the alloy steels—is materially increased by heat treatment. However, drastic heat treatment of steel castings involving quenching in a liquid medium is strictly prohibited in *A. S. T. M. Specification A-95-26T* on account of the danger of permanently injuring the castings by abnormally stressing them in the quenching process. The heat treatment required by this specification consists of annealing, or normalizing, or normalizing followed by annealing, or normalizing followed by a drawback to a temperature below the critical range. It is well to remember in this connection that high physical properties

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secured by heat treatment are reduced by long exposure to high working temperatures unless the drawback temperature is well above the working temperature to which the metal will be subjected in service, and that long exposure to working temperatures above 1,000 F will remove all excess strength secured by heat treatment.

Valve Trim Materials

The parts of a valve designated as the valve trim or trimmings are located at the vital points of attack by heat, corrosion, erosion, abrasion and wear, and consist of such parts as the valve seats, stem, bonnet bushing, stuffing box bushing, stuffing box gland and yoke nut. These parts are often made removable so that they can be replaced when they become injured and the valve can then be re-installed for another period of useful service. Different trim metals are required to withstand a great variety of service conditions in the many different processes to which valves are applied in industry.

Requirements of Trim Materials

The requirements for a satisfactory trim metal are very exacting and include such qualities as non-corrodibility; coefficient of expansion similar to the valve body metal; suitable structure to provide a smooth seating surface; ability to withstand sliding friction without scoring, seizing or galling; physical properties that permit fabrication in the valve; and an equitable cost that will keep the finished product within the range of a highly competitive market.

The first requirement of non-corrodibility, due to the different corrosive conditions encountered in industry, quite evidently requires the use of more than one kind of trim metal because metals that give excellent service on some types of corrosive conditions are useless on other types of service.

The close agreement between the coefficients of expansion of trim and body metals becomes of increasing importance in the high temperature zone, and at high temperature the corrosion resistance of most metals and their ability to resist scoring, seizing and galling are greatly reduced, so it is readily apparent that the development of a suitable trim metal for high temperature service has not been an easy problem.

The last requirement of equitable cost is not as serious in the case of trim metal as it is for body metal because a much smaller quantity of the metal is involved, but it nevertheless remains an item of considerable importance.

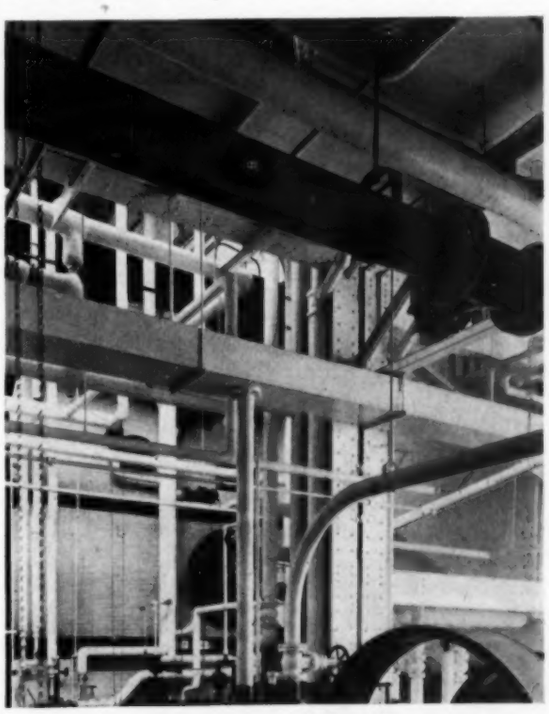
Bronze is quite generally used as a trim metal for general purpose use on fluids such as oil, water and gas at temperatures up to 150 F and for saturated steam up to 450 F. Bronze trim is corrosion-resistant under many of the ordinary service conditions, but for some corrosion conditions monel metal is used instead of bronze, and for others plain carbon steel or stainless steel is used to advantage.

Monel metal has been extensively used for a number of years and has proved quite satisfactory in superheated steam service at temperatures up to 600 F. As steam temperatures have risen monel has continued to give satisfactory service at temperatures up to 700 F, but at higher temperatures it has not always been up to requirements in regard to the coefficient of expansion, as evidenced by loosening of seat rings in service, and the resistance to scoring has not been as good as might be desired.

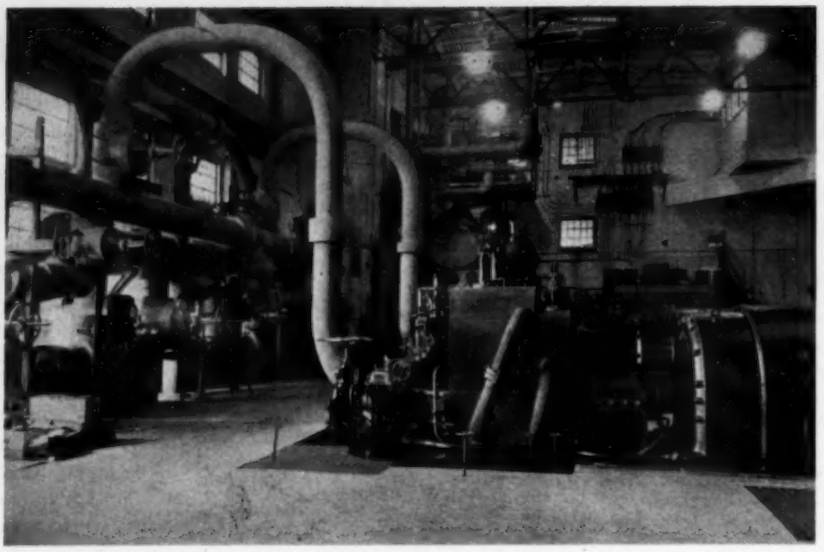
New Developments in Trim Materials

Up to a comparatively few years ago valve trim metals were limited to bronze, monel metal and plain carbon steel, but with the rise in steam temperatures and also the severe temperature and corrosion conditions of modern oil refinery processes the old trim metals did not fill the bill and the search for new metals to withstand to better advantage the new conditions has been going on apace for the past several years. Many types of alloys, both ferrous and non-ferrous, have been tried in various states of heat treatment and in various combinations of one metal against another, but the results in many cases were not satisfactory, due to failure to meet one or more of the basic requirements.

Out of this mass of experimentation several trim materials have emerged which are being extensively used in service. Two that might be mentioned are, *first,* stainless iron containing approximately 0.10 per cent carbon and 13.0 per cent chromium which has been widely adopted for general use in oil refinery service. This material is used in the heat treated condition, one seat being drawn at a lower temperature than the other so as to establish a substantial differential in Brinell hardness between the two seats. In some cases this metal does not



TYPICAL BOILER ROOM PIPING ILLUSTRATING METHODS OF INSULATING AND SUPPORTING HIGH PRESSURE-HIGH TEMPERATURE PIPING



Typical Turbine Room Piping

have the desired corrosion resistance, and the more resistant austenitic alloy containing 18 per cent nickel and 8 per cent chromium is being used to some extent. However, stainless iron, which has served so well on hot oil and hot oil vapor, has, in superheated steam service, been satisfactory in some cases and in other cases it has failed. On globe valves where the seats do not slide over each other under pressure to any great extent, it has been more satisfactory than it has on gates where considerable sliding contact of the seats is involved each time the valve is opened and closed.

The *second* trim metal referred to is a patented alloy steel containing an appreciable percentage of aluminum and having the property of developing an exceedingly high surface hardness when exposed to ammonia gas at a temperature of around 900 F. The surface hardness of around 1,000 Brinell which is developed by this process is due to the formation of nitrides beneath the surface of the metal, and this extreme hardness is well maintained at high working temperatures.

Although not as corrosion resistant as stainless iron under all conditions, this alloy is a very corrosion resistant metal and it is being used to an increasing extent as a valve trim material. While this metal was originally developed in Germany, a great deal of experimental research is being carried on in this country, both on the composition of the alloys best suited to the nitriding treatment, and on the detailed procedure of the nitriding process.

Research Continues

Experiments on various types of trim metals are being continued and further developments along these lines are anticipated as more knowledge is gained regarding the fundamental nature of the scoring of surfaces in sliding contact and of corrosion at high temperatures. The experiments to date appear to indicate that in order to avoid the tendency toward scoring, galling and seizing, it is essential that at least one of the seats shall be extremely hard, finished to a smooth surface and polished. When this is done the possibility of interlocking and tearing away the surface particles of the two seats is greatly reduced if not entirely eliminated.

Cast, Forged and Welded Pressure Containers

As previously mentioned, pressure containers made of steel castings have not always given satisfactory service because of defects in the castings, and while this condition has been largely corrected, some engineers show a preference for forged steel products. It naturally follows, therefore, that forged steel fittings and valves, which in the smaller sizes can be manufactured and sold on a competitive basis, are extensively used. In the larger sizes, however, where from the standpoint of safety any advantage that forgings may have over castings would be of even greater importance, the difficulties and high cost of production have prevented the general use of the forged steel product.

Future developments in these two methods of manufacture will determine whether steel castings will be able to retain their pre-eminence in this field, or whether the forging process will be able to compete with and displace castings. It should not be overlooked in considering this question, however, that forgings are not free from the possibility of interior defects. All forgings start from a casting which may contain defects that persist clear through to the finished product, and additional defects also may be introduced in the forging process. Consequently, it is evident that careful control of processes is necessary in the case of forgings just as it is in the case of castings if a uniformly reliable product is to be secured.

As for welded joints, the *A. S. M. E. Boiler Code Committee* rules, while accepting forge welded joints in boiler drums at an efficiency of approximately 70 per cent, prohibits the use of autogenous welding if the safety of the structure is dependent on the strength of the weld.

Before the advent of the present high pressure-high temperature service conditions much of the steel pipe used was welded, the smaller sizes being butt welded and the larger sizes lap welded. However, the new conditions have brought seamless pipe rapidly to the front and when the *American Standard B-16E* was set up covering working steam pressures up to 1,350 pounds at a temperature of 750 F, butt welded pipe was prohibited altogether and lap welded pipe was prohibited for pressures above 400 pounds. On the other hand, welded joints have been successfully used at high temperatures in Europe, and in the oil industry in this country autogenously welded pressure vessels have been in successful use for long periods in high pressure service at temperatures around 900 F.

Several new methods of manufacturing welded steel

pipe have recently been developed in this country in which welds of both the butt and lap joint types are made by special high production electric resistance welding machines. Both electric arc welded and electric resistance welded pipe are being extensively used for high pressure cross country oil and gas lines and for similar service. In Germany, also, special welding machines for making welded pipe are being actively developed, but there the gas welding process apparently is favored.

The great progress that is being made in improving the control of quality and uniformity of autogenous welds appears to indicate the probability of welded pressure vessels establishing their general acceptability in the high pressure-high temperature field, and the future dominance of seamless or welded pressure vessels will in that case become a question of economics rather than of safety.

Pipe Joints

The familiar method of joining pipes by means of tapered screw threads was originated prior to 1882 by the distinguished American engineer, Robert Briggs. Master gages were made up for the Briggs standard thread and it was jointly adopted by the manufacturers of piping materials and the *American Society of Mechanical Engineers* in 1886. Since then, certain additional sizes, details of gaging, tolerances and special applications have been incorporated in the standard. In 1919, its name was changed to the *American Standard Pipe Thread* and it was formally adopted as an American standard by the *American Engineering Standards Committee* (now known as the *American Standards Association*). This type of joint has many good features and is widely used in the smaller sizes. However, in the larger sizes it becomes more difficult to apply in a satisfactory manner, and in consequence of this, other types of joints are being used to an increasing extent.

Types of Joints

Numerous types of joints have been tried, some of which have successfully emerged from the acid test of actual performance in service and are now extensively used for the particular conditions to which they are adapted. A partial grouping is as follows:

1. Slip joints—in which the seal is made by some sort of packing material and the pipe is permitted to come and go to a limited extent, thus providing for a certain amount of expansion and contraction, and for misalignment due to laying the pipe on the uneven surface of the ground.

2. Fixed flange joints—in which the flange is rigidly attached to the pipe by some method. The methods most commonly used for this purpose are either screwing or rolling the pipe securely into the flange and seal welding the joint at the back of the flange. Flanges of this type are sometimes welded both front and back, but this practice has been largely discontinued because welding at two points may introduce undesirable stresses in the joint. When fixed flanges are attached by a method that depends upon the weld to carry the pipe line stresses they should be classified in group 5.

3. Lap joints with loose flanges—in which the end of the pipe is forged and machined so that the seat is made against a continuation of the inside wall of the pipe, usually by means of a gasket.

4. Seal welded lap joints with loose flanges—in which the end of the pipe is forged and machined similar to the lap joint previously described, but instead of using a gasket the seal is made by welding the edges of the two pipes together. In this type of joint the weld serves only as a seal and the pipe line stresses are carried by the flange bolts in the conventional manner.

5. Welded joints—in which dependence is placed in the weld both for sealing the joint and for carrying the pipe line stresses.

In high pressure-high temperature service screwed joints are not usually considered satisfactory in sizes larger than 2 in. because of danger of the thread connection becoming loosened in service due to unequal expansion of the pipe and flange resulting in compression of the male thread and stretching of the female thread. Slip joints are not suitable for high temperature service because of the method of sealing the joint and consequently will not be further discussed.

The fixed flange joints are used rather extensively where temperature and pressure conditions are not too severe, but obviously their use involves some trouble in assembly due to difficulty in alignment of bolt holes. Fig. 27 shows typical examples of this type of joint.

The lap joints with loose flanges, while somewhat more expensive than the fixed flange type, offer several real advantages, the writer believes. In this type of joint the pipe wall has full strength at all points unweakened by pipe threads or by excessive rolling. The joint is sealed against the inside wall of the pipe, thus preventing any possibility of leakage through the bore of the flange; the flanges are loose so that they can be readily swiveled to bring the bolt holes into alignment, and the stresses in the flange itself are reduced because the flange is not subjected to the torsional and bursting stresses introduced in making up a screwed joint, or the bursting stress introduced by rolling the pipe into the flange.

It is of interest to note that the lap joint was conceived in 1896 when George I. Rockwood, freshly gradu-

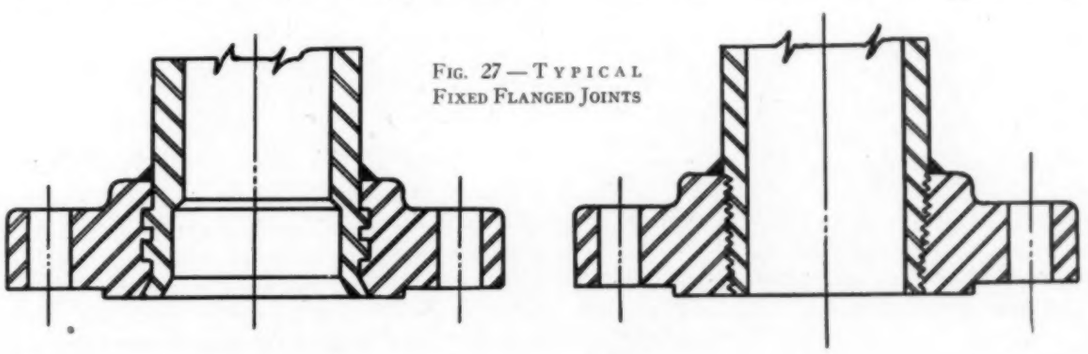
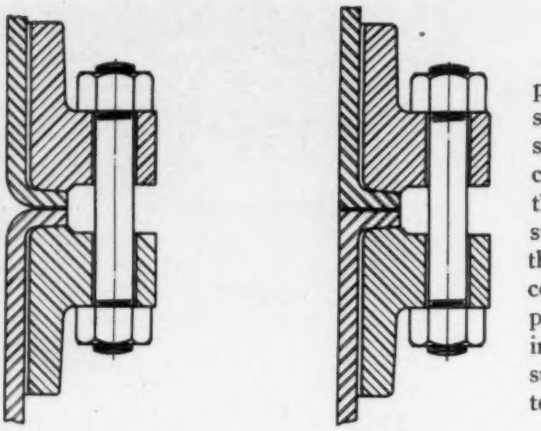
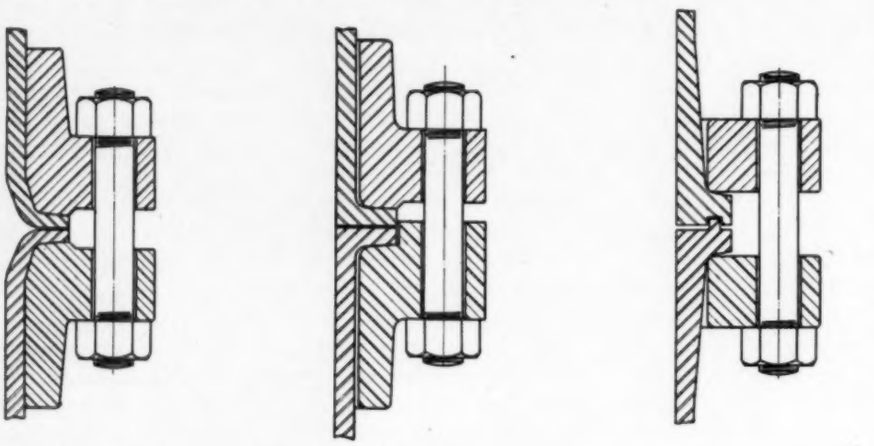


FIG. 27 — TYPICAL FIXED FLANGED JOINTS



ROUND CORNER LAP JOINT SQUARE CORNER LAP JOINT

FIG. 28—TYPICAL LAP JOINTS WITH LOOSE FLANGES



TAPERED LAP JOINT MALE & FEMALE LAP JOINT TONGUE & GROOVED LAP JOINT

ated from the *Worcester Polytechnic Institute,* startled the profession by the discovery that it was possible to flange over Bessemer steel pipe, which the pipe mills at that time were just commencing to make. The Rockwood flange, however, was securely attached to the pipe; and later Charles Van Stone of Boston, who supervised the manufacture of a great many of the early Rockwood joints, improved the design by making the flange loose. The lap joint with loose flange has been very extentively used since that time and it is commonly known today as the Van Stone joint. Fig. 28 shows four types of Van Stone joints in common use, all of which use flat asbestos or metallic gaskets.

The sealed welded type of lap joint is essentially the same as the lap joints previously described, except that no gasket is used and the joint is sealed by welding together the outer peripheries of the two laps. This type of joint is rather expensive to install and difficult to take down and replace if it becomes necessary to break the joint, but if properly installed eliminates much of the trouble from joint leaks and is extensively used in high pressure steam plants. Fig. 29 shows two types of this joint.

The second illustration with the thin welding lips is claimed to be an improvement over the older type because it can be welded without adding any filler metal and the heat generated in welding is considerably reduced.

Welded Piping

Welded joints which are so designed that the piping stresses are carried by the weld are not sanctioned for high pressure-high temperature service by the steam engineering fraternity in this country, but they are being extensively used in the oil industry with uniformly satisfactory results, and growth in the use of welding is one of the striking phases of development in pipe line construction. The great improvement in welding processes and in the control of welding technique in recent years has contributed materially to the substantial progress that has been made. Needless to say, when dependence is placed on welds for carrying the piping stresses, great care should be exercised in the selection and training of welders, as well as in careful supervision to see that the specified technique is always followed, and in the inspection and testing of the joints as is necessary with any type of job.

When this type of joint is used, special precautions should be observed to prevent the weld metal from running through into the pipe and creating obstructions that interfere with flow, or will be later carried along to lodge in valves or other equipment in such a way as to damage them or interfere with their proper functioning.

Fig. 30 shows three types of welded joints. The cup weld eliminates the necessity for clamps to hold the pipe in place while welding. On pipe sizes above 2 in. the cup weld is sometimes reinforced by four spot welds placed 90 degrees apart near the opposite end of the joint, and for pipe sizes 10 in. and larger additional spot welds may be provided so that the circumferential distance between them will not exceed 6 in.

The sleeve weld, shown in the third illustration, is applicable to conditions where unusual stresses are encountered. Welded joints for pipe lines, when properly made, undoubtedly offer many advantages and confidence in their reliability is growing throughout the world. In laying out a system of this character, however, "overenthusiasm" should be curbed and a sufficient number of flanged joints should be provided so that the line may be readily opened up at such places as may be necessary for repairs, replacements and cleaning out pipe lines so as to keep the system in proper operating condition.

Gaskets for High Pressure Piping

Fig. 31 shows five types of facings for asbestos and metallic flat gaskets and four types of facings for metallic ring gaskets which are all used in high pressure-high temperature service. On the wide faced types, asbestos gaskets are ordinarily employed, and for extremely high pressures the narrow faced types are gen-

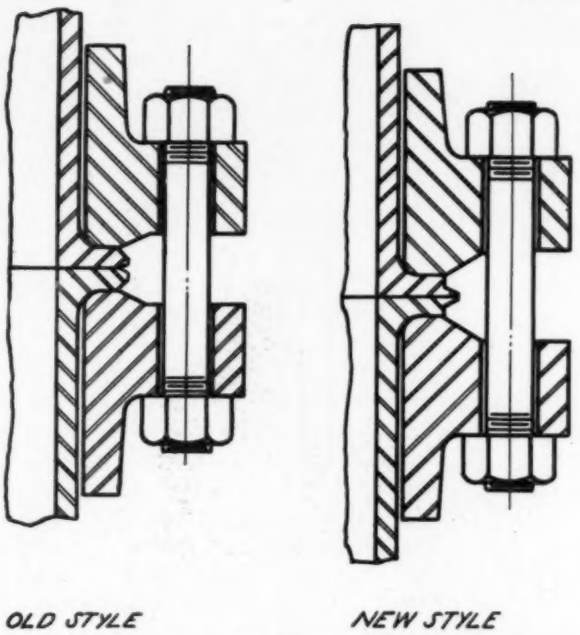


FIG. 29—TYPICAL SEAL WELDED LAP JOINTS

erally used, in conjunction with metallic gaskets. The flat faces may be finished smooth, or with a phonographic finish according to the preference of the designing engineer, but it should be pointed out that the smooth finish does not afford a good grip on the gasket and most manufacturers furnish the phonographic finish unless otherwise specified. The phonographic finish is ordinarily made with a 60 degree angle round nose tool fed across the face of the flange at the rate of 1/32 in. for each revolution.

Bolts for Flanged Joints

The bolts used for flanged joints in high pressure-

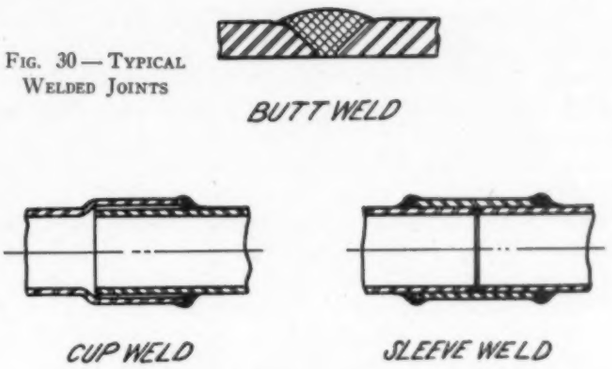


FIG. 30 — TYPICAL WELDED JOINTS

high temperature service are required by the *American Standard B-16E* specification to be studs, threaded for nuts at both ends and the material from which the studs are made must be a heat treated alloy steel conforming to *A. S. T. M. Specification No. A-96*. This specification permits the use of three classes of steel ranging from Class *A*, 95,000, to Class *C*, 125,000 pounds per square inch ultimate tensile strength, but the general tendency seems to be to use the highest grade steel, Class *C*, for high temperature studs.

Some engineers specify studs threaded throughout their entire length in order to keep the unit stress and the unit strain uniform throughout the entire length of the stud. This, however, increases the cost of the studs and has not been generally adopted. Studs threaded at both ends in the ordinary way are giving satisfactory service under high temperature conditions. For high temperature service the heat treatment used for studs should, of course, employ a drawing temperature well above the working temperature in service so as to insure retention of the high physical properties imparted by heat treatment, and as the working temperature increases this requires the use of higher alloy steels.

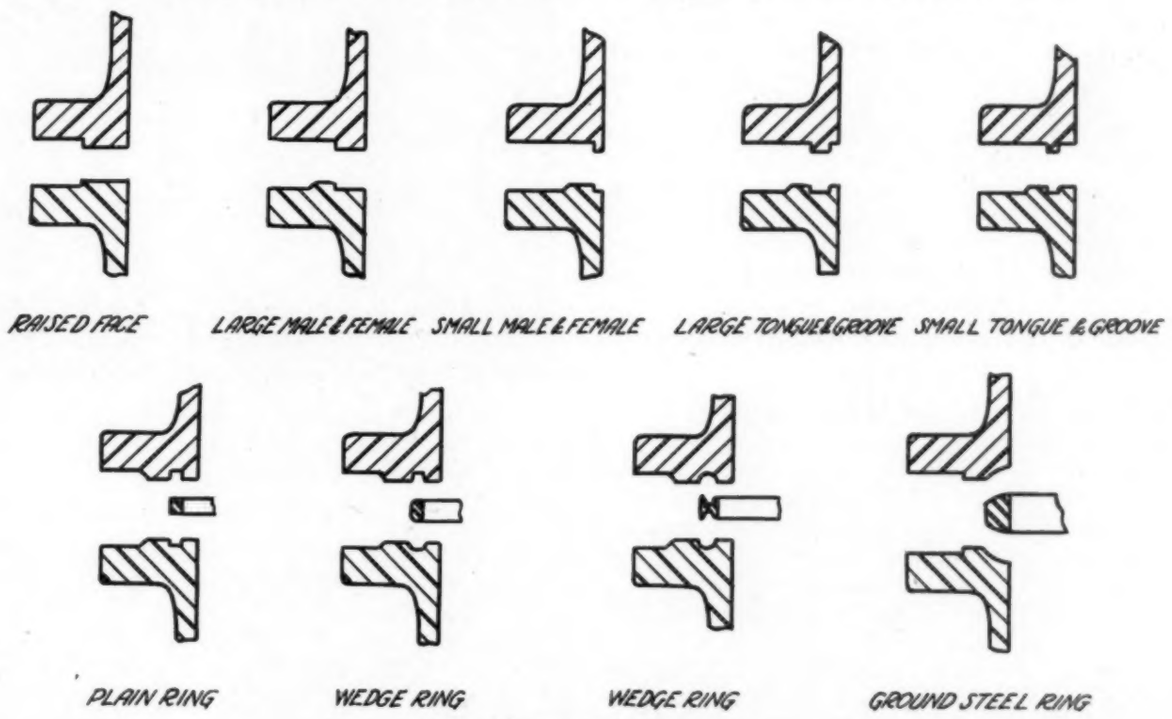


FIG. 31—TYPICAL FLANGE FACINGS

General Features and Conclusion

High pressure-high temperature piping systems in general involve a greater hazard than low pressure-low temperature systems, and consequently a proportionately greater amount of study and care should be devoted to their design, installation and maintenance.

Ample working space should be provided so that repairs can be readily made; control valves should be placed in accessible locations so that prompt and speedy action will be possible in cases of emergency, as well as in the normal operation of the system.

The piping layout should be carefully planned to accommodate the greater amount of expansion due to the high working temperature without subjecting the pipe and joints to abnormal stresses. Anchorages should be securely fastened to the pipe and rigidly held in position so that they will perform the functions intended.

Proper slope for drainage, bleeder connections, clean-outs, relief valves and provision for elimination of air binding should be provided where necessary. Ample supports properly spaced should be provided and these should be designed so as to permit the pipe to come and go freely without introducing auxiliary stresses due to resistance of the supports.

Insulation of a suitable type should be used to conserve heat losses and special pains should be taken to see that the design, installation and maintenance are such as to prevent deterioration of the insulation in service through temperature variations of the piping systems and improper functioning of the pipe supports, or through the action of outside agencies to which the pipe line may be subjected.

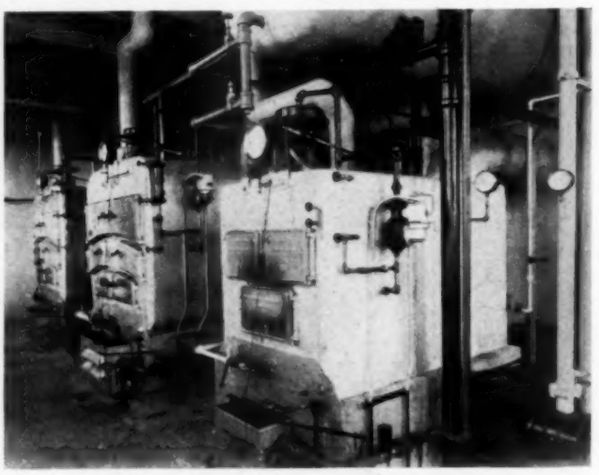
In the present state of knowledge regarding the performance of metals in long continued service at temperatures of around 1,000 F and higher, a new and important duty devolves upon the maintenance man, and that is to keep careful watch of the various elements of the piping system and make sure that no abnormal creep is taking place. Laboratory tests have conclusively shown that when metals fail due to creep at high temperature they invariably give warning a long time in advance of failure by a comparatively rapid rise in the rate of creep. Consequently, the abnormal extension of any part of the pressure containing system would indicate that the useful life of that particular part was over, and data gained in this way would be very helpful in re-designing the part to provide greater strength.

THE NEW BUILDING OF THE EASTERN OUTFITTING CO. IN LOS ANGELES AND A VIEW OF THE BOILERS, WHICH WERE INSTALLED "ON THE ROOF"

Boilers Installed in Office Building Pent-House

TWO low pressure, cast iron boilers, designed for burning either oil or gas and a boiler for supplying hot water, are located in the pent-house of the new building of the Eastern Outfitting Co. in Los Angeles. It was desired to use the basement of the structure as a sales floor, so the heating plant was located on the roof to avoid a sub-basement. The system was designed by R. M. Storms, mechanical engineer with Claud Beelman, architect for the building.

The heating boilers have a capacity of 225 hp. The oil burned is of 23 degrees Baumé, the storage tank being located under the sidewalk. Two rotary spiral gear pumps, operating against 125 lb. pressure, are each capable of delivering seven gallons of oil per minute. Two oil lines run from the basement to the roof, there being a return line which feeds into the oil pump line. Each of the oil pumps is driven by a 1½ hp. a-c motor.



The three boilers (one of them for supplying hot water) are fitted with low pressure air type oil burners; a small compressor supplies air for atomization. The gas system was installed for emergency use, and the change from oil to gas can be made by throwing an electric switch. The gas burners are controlled by individual hand-operated gas cocks; the burners operate on 1 lb. pressure.

Controlled Cooling *is* Profitable

By Malcolm Tomlinson*

COOLING has many practical applications in the industrial field; the various methods used, in the effort to produce the necessary results, involve the use of refrigeration and air conditioning equipment. The practicability of each of these methods depends upon a number of factors which include the quality desired for the product and the amount of imperfect or spoiled goods which can be permitted without seriously affecting profits. The rate of air motion enters into each of these problems of production, but, as it is usually quite uniform in each one of these various systems, it is not as important in its effects as the temperature of the air and the relative humidity.

Machines Replace Human Labor

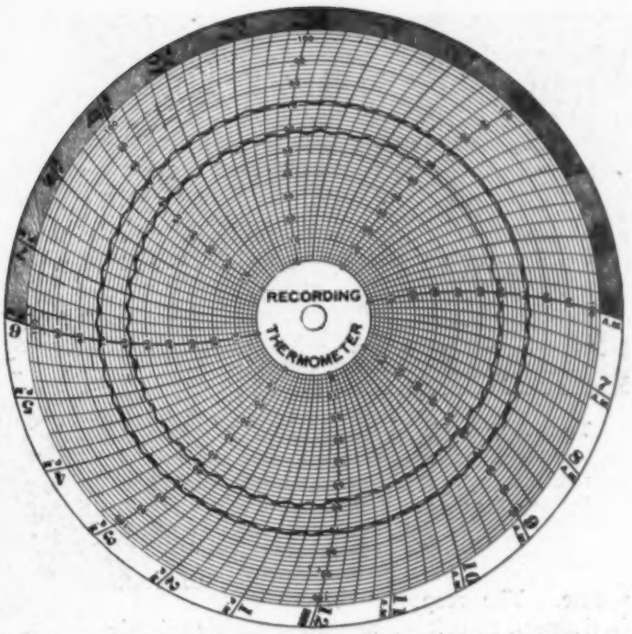
Quality and the percentage of imperfect goods change at the whim of the consumer; in other words, the manufacturer must furnish the quality desired in order to keep the market. As a whole the tendency is toward better quality in all products at a relatively lower cost. With the growth of such demands, human labor is gradually replaced with semi-automatic or automatic machinery. Such changes always bring new problems to the production or the manufacturing department of factories. The adoption of such machinery is usually quite rapid.

It should not be forgotten how semi-automatic and automatic machinery enters the industrial field. The process is always the same, to reduce costs by replacing human labor. The same process of improvement should apply equally well in the control of operating equipment. It will be interesting to see just how well automatic types of control can compete, in the cooling field, with the human.

Temperature and relative humidity are both important factors where cooling enters into production. In all plants there is more or less thought given to the use of temperature but without much regulation of the relative humidity. Too few plants which use cooling methods have air conditioning equipment where humidity control is a part of the installation.

Candy Industry Needs Controlled Humidity

A typical example is found in the candy industry. It has not been so long since every large candy factory which produced chocolates had a big problem in disposing of imperfect ones. Some of these plants have solved, or partially solved, this problem by the use of air conditioning systems which are equipped to regulate the relative humidity. Others try to avoid, as much as possible, the use of such equipment.



AN ACTUAL CHART TAKEN FROM A RECORDING INSTRUMENT IN AN AIR CONDITIONED AND DEHUMIDIFIED ROOM IN A PRINTING PLANT. WEATHER REPORT FOR THAT DAY AT 4 P. M. WAS 96 F OUTSIDE. NOTE CHART STEADY THROUGHOUT ENTIRE DAY. OUTSIDE LINE, DRY BULB TEMPERATURE; INSIDE LINE, WET BULB TEMPERATURE. RELATIVE HUMIDITY CONSTANT, VARYING NOT OVER TWO PER CENT

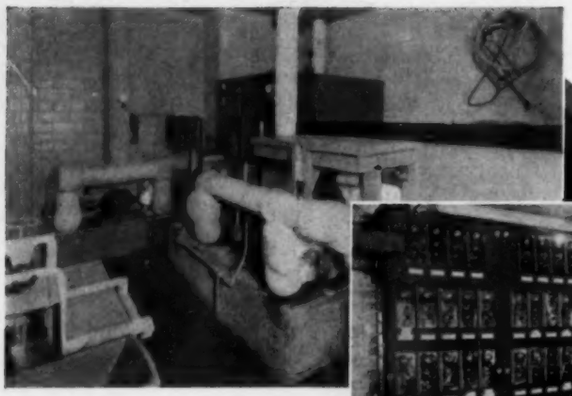
A case of the latter kind may well be cited for illustration. In a certain candy factory warm chocolate, in molds, passed on a conveyor through a refrigerated room. After cooling, the conveyor carried the chocolate bars, still in the molds, into another room for wrapping purposes. This room was mechanically ventilated, but the weather produced was not much different from that outside; in warm weather it was quite humid. The chocolate bars would sweat and stick in the molds After removal from the molds a fairly large percentage of the bars would crack. The product was not processed in the best manner or there would have been no such losses. The difficulty experienced was mainly due to the extremely high humidity which followed a cooling process. The packing room should have been regulated, by means of cooling, in such a manner as to balance the conditions in the refrigerated room. This would have required humidity control.

Cooling in cold storage plants was once conducted without any regard to humidity. As a general thing, the relative humidity was higher than was needed. Now we know that bacteria, molds and fungi growth are all encouraged by high relative humidities.

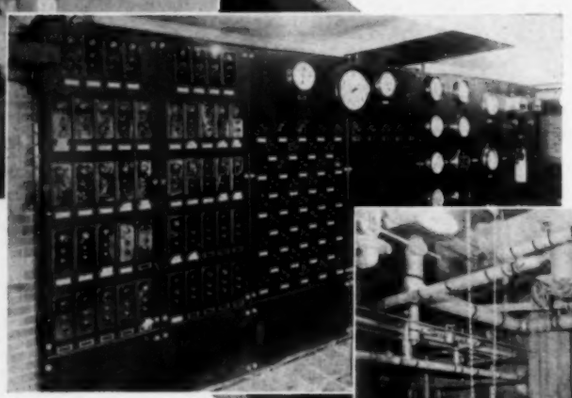
All ventilating, cooling and complete air conditioning systems provide artificial weather. There are, of course, differences in the conditions maintained by each system. In the main these differences lie in the fluctuations permitted in the control of the temperature and the relative humidity.

The degree of regulation provided with each installation determines the improvement afforded, by the artificial weather furnished, over the weather supplied by

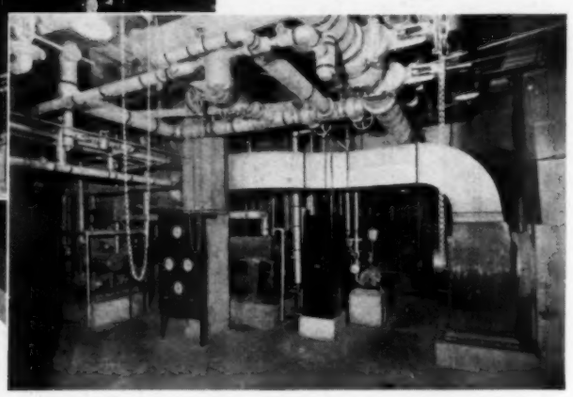
* Consulting engineer, Westtown, Pa.



THE AUTOMATIC ELECTRIC CONTROL UNITS ON THE REFRIGERATING UNITS IN THE FISHER BUILDING, DETROIT



CENTER—A GOOD EXAMPLE OF AUTOMATIC REMOTE CONTROL, SHOWING INDICATING CONTROL BUTTONS AND INDICATING AND RECORDING INSTRUMENTS LOCATED NEAR THE POINT OF CONTROL



SHOWING THE AUTOMATIC CONTROL EQUIPMENT FOR THE AIR CONDITIONING EQUIPMENT IN THE THEATER MACHINE ROOM

nature. The respective effectiveness, therefore, depends upon how closely these systems can hold the fluctuations of artificial weather to a minimum. Now, since they can all be equipped for human, semi-automatic or automatic control, it is evident that the amount of fluctuation of temperature and relative humidity varies with the kind of control furnished.

Human Control

Human control is the kind often employed. In such cases the wise manufacturer has his operator keep an hourly log of certain temperatures for the permanent record. With this type of control, the constant adjustment of the cooling equipment varies with the attention given by the operator. It is not to be expected that this control gives a close regulation of temperature or relative humidity. This method also involves a daily expense for labor.

Advantages of Automatic Control

Automatic control is the other extreme. With instruments conditions can be kept so close that the temperature will not vary more than a half-degree or the relative humidity a half per cent, if need be. Such a control involves a higher first cost but its upkeep is extremely small and, when rugged in construction, it will give real service for long periods of time. It has none of the inconsistencies of a human being and it does not know the word fatigue. Every minute it measures, records and controls the slightest fluctuations in temperature and humidity. It can also be equipped so that the control which it furnishes is based upon temperature or humidity observations at a number of points which are widely separated. In this way it is prepared to give an average or mean of the conditions actually existing and, at the same time, catch any tendency towards change before it gets beyond the variation permitted. No human being can make so many observations in the equivalent time interval and no log can show at a glance the same facts that are to be found quickly on automatically charted records of such controls. Best of all, accuracy is fixed; every observation and adjustment made is held within the predetermined limit. Of course, with different processes, different degrees of accuracy are required.

The need for a type of control, in cooling, which is automatic can best be appreciated by a consideration of the effect of fluctuating weather. It is not unusual for the outside weather to change greatly in a short space of time. For instance, air temperatures usually vary 15 to 25 degrees in the course of 12 hours. Sometimes they drop as much or more in only a few hours.

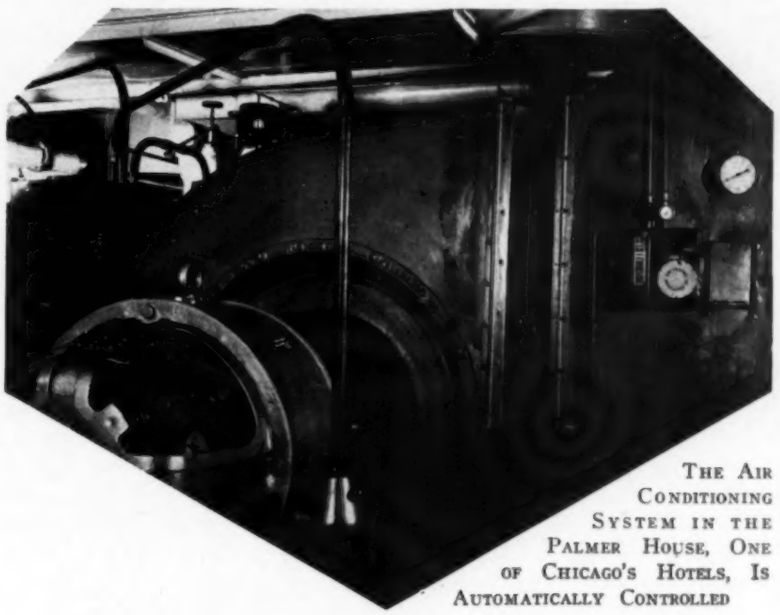
Suppose we assume an outside temperature of 70 degrees, a relative humidity of 50 per cent and an unchanging absolute humidity. Drop the temperature 15 degrees. This action drives the relative humidity up to 86 per cent. Raise the temperature a like amount above 70 and the relative humidity will drop to 30 per cent. It is thus evident that, at temperatures near normal for a human being, a change of one degree will mean a change of from 1¼ to 2 per cent relative humidity.

As the absolute humidity, which was held at a fixed point in our problem, ordinarily varies constantly there can be no question but that very small changes in temperature may have a great effect on the relative humidity.

In view of these facts, it is evident that temperature control can be used to a considerable extent in controlling the relative humidity. It is also clear that, where the control of both of these two weather factors is had, only the slightest of atmospheric fluctuations will occur.

Human control, then, can not give the same regulation as the automatic. We have already seen that human operation of machinery can not compete with the automatic. But the question will be asked "How close can human control hold the cooling sys-

tem?" No one can give an exact answer to that question. Too many factors are involved. Where the operator must depend on thermometers which can not be read much closer than a degree and where no direct reading humidity instruments are available, temperatures and relative humidities may vary from 2 to 5 degrees or from 2 to 10 per cent before the cooling equipment can be adjusted to meet the changing conditions. Perhaps this may not be a matter of concern in some processes; in many others, it is.



THE AIR CONDITIONING SYSTEM IN THE PALMER HOUSE, ONE OF CHICAGO'S HOTELS, IS AUTOMATICALLY CONTROLLED

Savings Realized Through Automatic Control

It is a well known fact that fluctuating temperatures in heating systems always mean a greater fuel expense than is had where precise temperature control is had. Therefore, it would seem that human control of cooling equipment will involve higher heat and power costs than automatic control. This is not the only saving in favor of automatic control. In addition there is a saving in labor; there is also the saving due to reduction or elimination of spoilage of goods. It will be found, after a careful study of the possibilities of each method of control, that automatic control pays for itself in a very short space of time.

Automatic control is eminently suitable for obtaining better results from inexpensive equipment than many engineers realize. Take ventilating systems as an example. For cooling purposes their limitations are usually such that they will only give about two degrees of cooling. With automatic temperature control, fluctuations of the temperature are eliminated, to all intents and purposes, and the temperature is regulated in such a manner as to give a fairly good control of the relative humidity. Of course, to do a first class job, it is necessary to have a direct reading relative humidity indicator or recorder on duty.

With intelligent control of this sort it is possible to obtain advantage of the cooling powers of the relative humidity. This method of controlling ventilating systems for cooling purposes has not the advantages of a complete air conditioning system with refrigeration, but it will give results which will meet many needs.

With complete air conditioning systems, which have means for putting moisture into the air, automatic control of temperature alone can be used, as already shown, for a rough control of the relative humidity. The combined control of temperature and humidity, when automatic, gives a result suitable for the finest and the most exacting product.

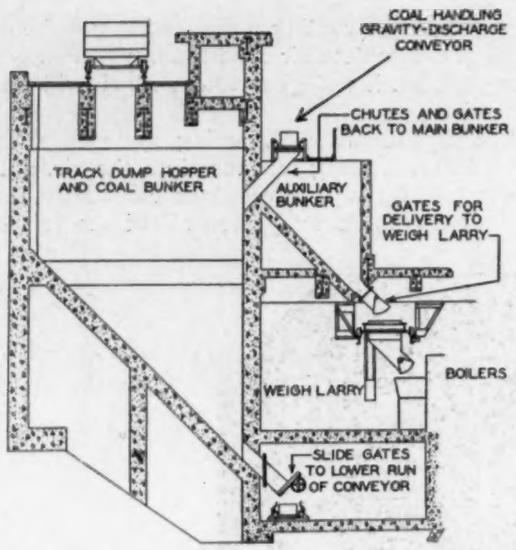
It may be argued that such precise control as is here advocated is only needed in a few processes while the majority of processes can be served adequately by a less expensive type of control. It must be remembered that this type of control makes the use of less expensive systems practical and that precise control with less expensive systems means a lower first cost than the more expensive machines for the same purpose which are equipped with only ordinary controls.

It is evident that careful consideration of the proper control for cooling equipment can not only lead to lower installation expense but can also supply the refinement desired in weather fluctuations at an operating cost much lower than is usually experienced. Automatic control is profitable and its advantages are particularly of interest to those industries which need cooling equipment.

The annual index to the American Society for Testing Material's Standards and Tentative Standards has been published recently. Dated as of September, 1930, 427 standards and 155 tentative standards are indexed. Included in the 116-page booklet is a price list of copies of A. S. T. M. Standards.

The index is paper bound, six by nine inches in size. Copies may be obtained free of charge from the A. S. T. M. at 1315 Spruce st., Philadelphia, Pa.

Coal and Ash Handling for Boilers


COAL HANDLING GRAVITY-DISCHARGE CONVEYOR
CHUTES AND GATES BACK TO MAIN BUNKER
TRACK DUMP HOPPER AND COAL BUNKER
AUXILIARY BUNKER
GATES FOR DELIVERY TO WEIGH LARRY
BOILERS
WEIGH LARRY
SLIDE GATES TO LOWER RUN OF CONVEYOR

A Cross Section of the Coal Handling Equipment.

THOUGH Chicago's Merchandise Mart is the world's largest building, there is nothing particularly unusual about the heating system, save for its size. The same principles used in heating a smaller structure were applied merely on a larger scale. Located on the north bank of the river on air rights over the tracks of a railroad, the building is eight or nine times the size of an average skyscraper. The site alone is 724 feet in length and 326 feet in width, while the height from track level to the roof of the tower measures some 375 feet. Excluding the track area under the building and the 6-story central tower, the eighteen floors of the Mart contain an approximate floor area of 4,000,000 square feet and a cubic content of almost 50,000,000 cubic feet.

Perhaps two characteristics of the heating system are unusual enough to merit mention. High pressure steam is piped to the top of the building, which serves to give the system increased flexibility to meet wide temperature changes. Also, all of the direct radiation is located on the perimeter of the building, all other spaces being heated by the ventilating air.

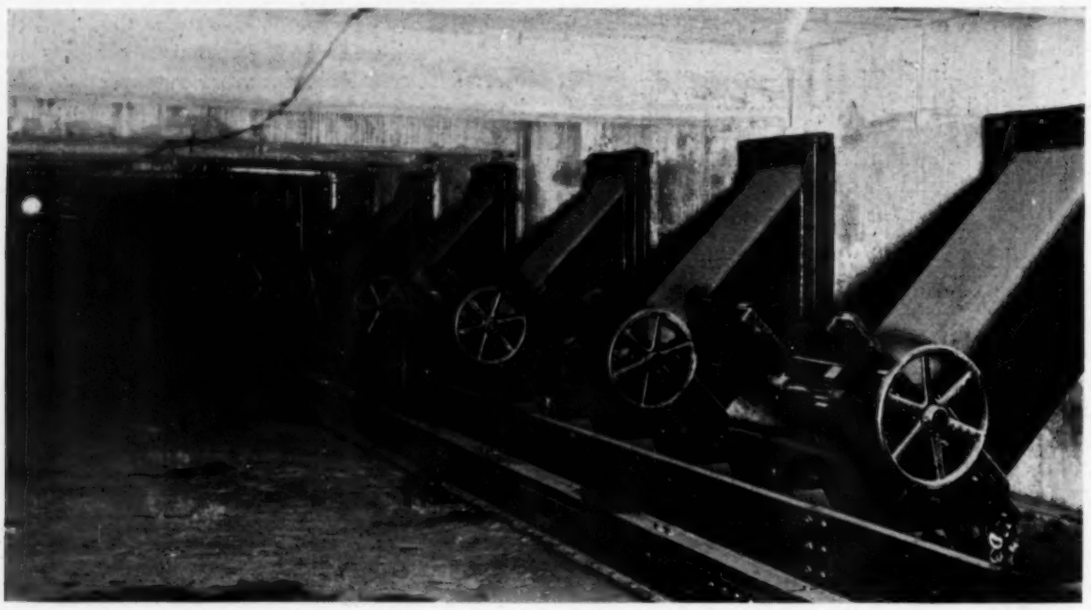
Capacity of Boilers

Of the seven boilers, five have a normal capacity of 500 hp. each, and two, which are primarily for auxiliary service, have a rating of 250 hp. each. All of the boilers are of the bent water-tube, four-drum type and supply a maximum radiation of well over 300,000 square feet.

The five larger boilers are 13 feet, 10 inches by 23 feet, with 528 tubes apiece. The auxiliary units are 8 by 23 feet and contain 264 tubes each. All of the boilers are set in bricking.

Boiler and Pump Rooms Entirely Underground

The boiler and pump rooms of the Merchandise Mart represent a unique method of construction. They are located entirely underground, the floor being about 80 feet beneath the railroad tracks and 50 feet below the river level. This section, which also houses a coal storage and handling plant, is all of steel frame and re-in-



A View of Part of the Thirty-Nine Slide Gates Which Discharge the Coal from the Bunkers Into the Conveyor

By T. H. Monaghan*

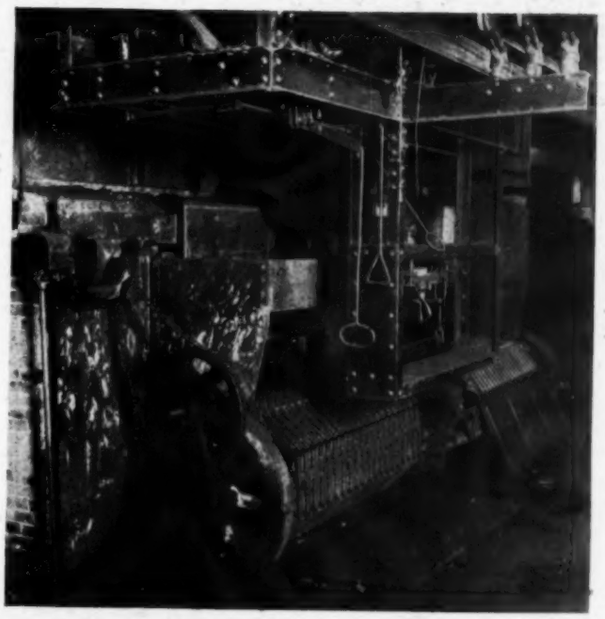
Fifty Feet Under Chicago River

THE WORLD'S LARGEST BUILDING IS CHICAGO'S RECENTLY COMPLETED MERCHANDISE MART. THE AIR CONDITIONED STUDIOS OF THE N.B.C., LOCATED ON THE 19TH AND 20TH FLOORS OF THE MART, ARE AMONG THE BEST EQUIPPED IN THE COUNTRY

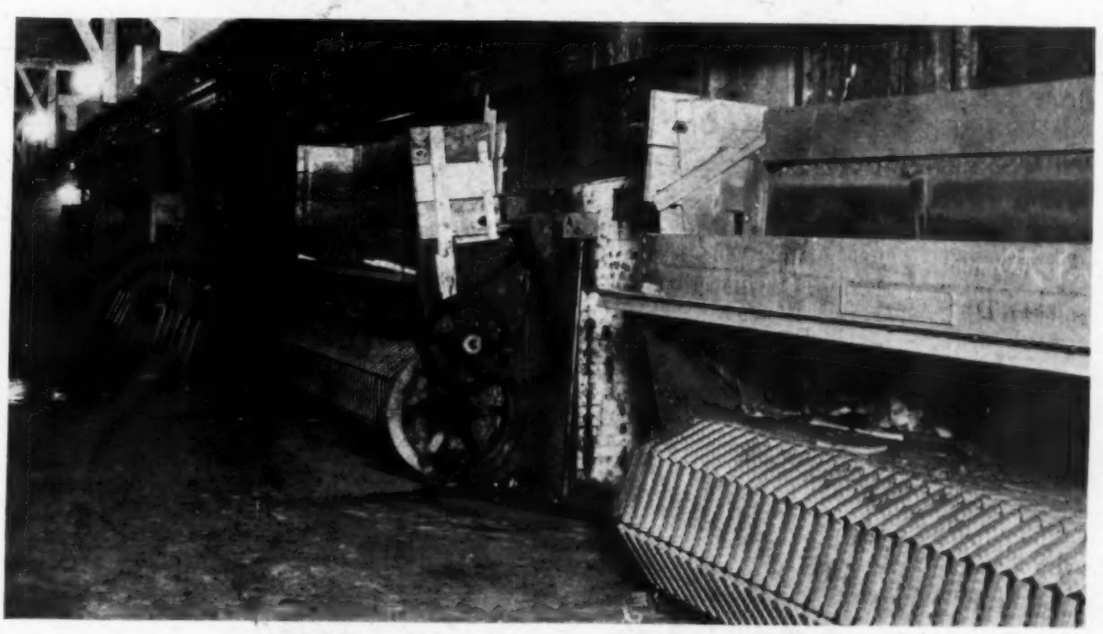
forced concrete walls. Under the boiler room are 556 caissons, each with an average diameter of seven feet, flared at the bottoms to provide maximum solidity. Upon these caissons rests the foundation of the building. The underground section measures 135 by 60 feet, with a ceiling 35 feet high.

The Coal Bunkers and Conveyors

The problem of supplying coal was met by installing a series of concrete bunkers directly opposite the boiler settings.

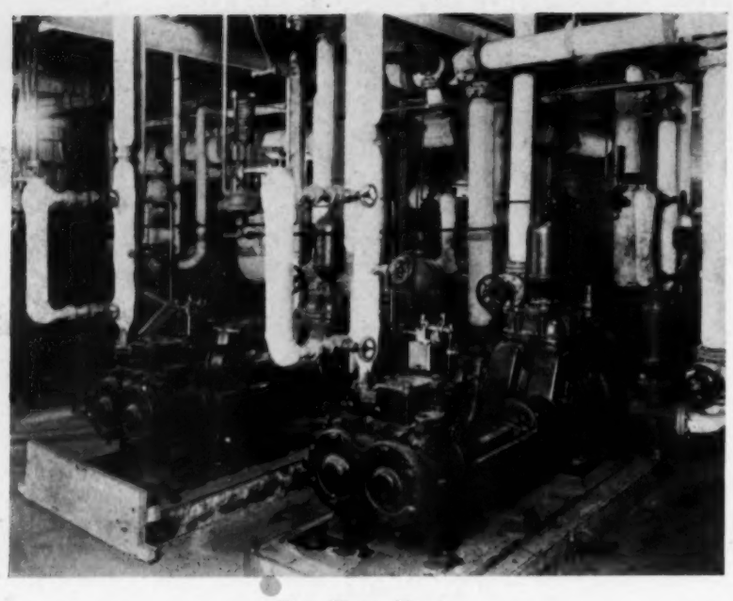


LEFT—THE TRAVELLING WEIGH LARRY, IN DISCHARGE POSITION



A GENERAL VIEW OF THE STOKERS. FIVE OF THE BOILERS HAVE A NORMAL CAPACITY OF 500 HP. EACH; THE OTHER TWO ARE EACH RATED AT 250 HP.

* Robert Gordon, Inc., Chicago.



THE PUMP ROOM

It is estimated that almost 160 tons of coal daily will be required in severe winter weather to keep the large boilers in steady operation. The average daily consumption for the entire year is 75 tons, or approximately 30,000 tons annually.

Coal is delivered immediately into the bunkers, which have a total 3,000-ton capacity, from railway dump cars on the tracks above the boiler room. A grating above each bunker keeps out all foreign material and pieces of coal larger than four inches in diameter. From the bunkers, the coal is distributed as needed through one or more of 39 slide gates operated by racks and pinions into the lower run of a gravity discharge elevator, which conveys the coal to the auxiliary bunker. An upper discharge run of the conveyor delivers coal to a storage section at the rate of 30 tons per hour. This run is equipped with 8 slide gates and chutes with hand wheels on the operating shafts.

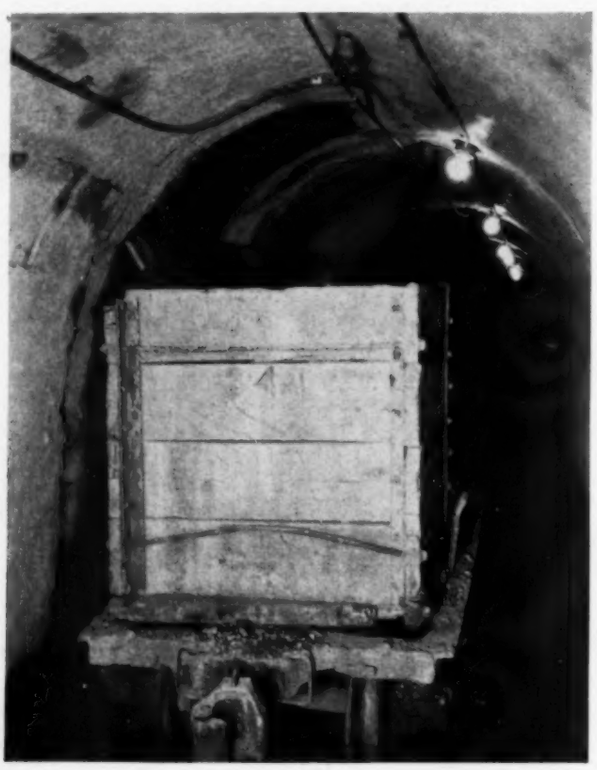
The auxiliary bunker temporarily stores all coal which is to be delivered directly to the stokers of each boiler. The coal passes through gates as needed into a weigh larry of 1,000 pounds capacity suspended from a scale which accurately weighs the fuel. The larry is of the self-propelled type and is motor-driven. It provides an accurate means of recording each boiler's consumption, so that each may be checked from time to time. Each boiler is also furnished with a water meter.

From the weigh larry, the coal is delivered into the stoker hoppers of the seven boilers through an undercut gate operated by an attendant from the floor of the boiler room. In the event of possible spontaneous combustion, the coal may easily be recirculated by withdrawing it into the lower run of the conveyor, then elevating it and finally discharging it through eight gates located along the overhead run of the conveyor. Here it is delivered back into the storage bunker.

Ashes Removed Through Tunnel to Lake

The method of ash disposal is as ingenious as that of handling coal. Clinkers and ashes are dumped by the chain grate at the rear into a concrete hopper, where they are conveyed through chutes to cars waiting in a tunnel under the boiler room. The tunnel locomotive brings in a train of empty railroad cars and places one under each ash chute. When they are loaded the train moves out and over to the lake front, where the ashes are dumped and used to fill in land for the 1933 Century of Progress Exposition.

The architects for the Merchandise Mart were Graham, Anderson, Probst and White of Chicago. John Griffiths & Son Co. were the general contractors. The heating contractors were Robert Gordon, Inc. G. A. Welles is general manager of the Mart. F. F. Sengstock is general superintendent of the building and H. J. Hipp is chief engineer.



ASHES BEING DISCHARGED INTO CARS FORTY FEET BELOW THE RIVER LEVEL, BEFORE BEING HAULED TO LAKE MICHIGAN FOR DUMPING

Selecting Sterilizers

Article No. 2

By Rollo E. Gilmore*

Mr. Gilmore discusses disinfectors, instrument sterilizers, utensil sterilizers, milk and bottle pasteurizers, bed pan washers and water sterilizers. Tables showing the approximate steam consumption (and, for electrically heated apparatus, the electric consumption), are given for most of the devices mentioned.

Proper sizes of sterilizers for use in surgeons' offices, major and minor operating rooms, emergency hospitals in industrial plants, delivery rooms, and groups of rooms are suggested.

This article is the second of a series; the first part was published last month.

Disinfectors

MATTRESS type disinfectors are large pressure sterilizers made in both the rectangular and cylindrical types for destroying germs in mattresses, blankets, linen, bed clothing, patients' clothing and supplies. They are also used for treating contents with formaldehyde, ammonia, or other gases. They are constructed with steam jackets of heavy iron, stay-bolted as is usual in high pressure steam boilers, tested to a hydrostatic pressure of 150 pounds per square inch, and the chambers tested to 30 pounds per square inch steam pressure.

They are equipped with radial locking arm doors, of boiler plate, when desired in one or both ends, which swing outward on heavy adjustable ball-bearing davits. A car is required, usually constructed of wrought iron with a galvanized wire mesh basket. The car track is of the extension type with braced frame.

Air Must Be Eliminated

The main accessories include pressure and safety valves, vacuum breaker, air exhauster, reducing valve, formaldehyde-ammonia generator, gages, steam trap, etc. Inadequate methods of draining of condensation from these disinfectors have produced strains sufficient to cause leaks. Traps of a type that automatically and positively eliminate air as well as condensation are necessary.

Standard sizes range from 24 inches diameter by 60 inches long, to 60 inches in diameter by 114 inches long, and the rectangular types range from 24 inches by 24 inches by 36 inches long to 52 inches by 64 inches by 108 inches long.

While the cost of the cylindrical disinfectors is usually less than that of the rectangular, they have the disadvantage that in using them the mattresses must be rolled up, which tends to tear them. The smallest mattress is 36 inches wide, so that a 36-inch diameter disinfector would be required when a mattress is to be rolled or a 42-inch wide rectangular size used when mattresses are to be spread flat on shelves.

* President, Chicago Association of Consulting Engineers; engineer, Schmidt, Garden & Erikson, architects.

Steam Consumption of Disinfectors

The disinfectors and rectangular type dressing sterilizers should be operated to maintain 45 pounds constant steam pressure in the jacket for a minimum period of thirty minutes during the sterilizing cycle. The steam consumption during the period of operation will be approximately as follows, according to the writer's experience:

Size, Inches	Steam Consumption Pounds per Hour for Average Period of Operation
24 x 24 x 36	59
24 x 36 x 48	85
24 x 36 x 78	132
30 x 42 x 84	175
36 x 48 x 84	185
36 x 54 x 96	234
42 x 48 x 96	234
48 x 54 x 96	268
48 x 60 x 96	297
60 x 66 x 108	350
24 diam. by 66	90
30 diam. by 86	128
36 diam. by 88	163
40 diam. by 93	179
48 diam. by 93	230
56 diam. by 93	248
60 diam. by 108	315
60 diam. by 222	622

Connections to the sterilizers are a one-inch steam supply (minimum); one inch steam drip, or return; one and one-half inch waste lines; and two inch separate local vent or vapor exhaust to atmosphere (preferably through the roof).

Instrument Sterilizers

The rectangular instrument sterilizers are often referred to as the boiling or non-pressure type, inasmuch as they boil the surgical instruments, syringes, etc., in sterilizing. They are constructed with a single cold rolled copper or brass shell of a rectangular receptacle pattern, plated outside and lined inside in the larger sterilizers with block tin, and attached to a heavy dished bronze bottom.

The covers are usually designed to seal closed in an

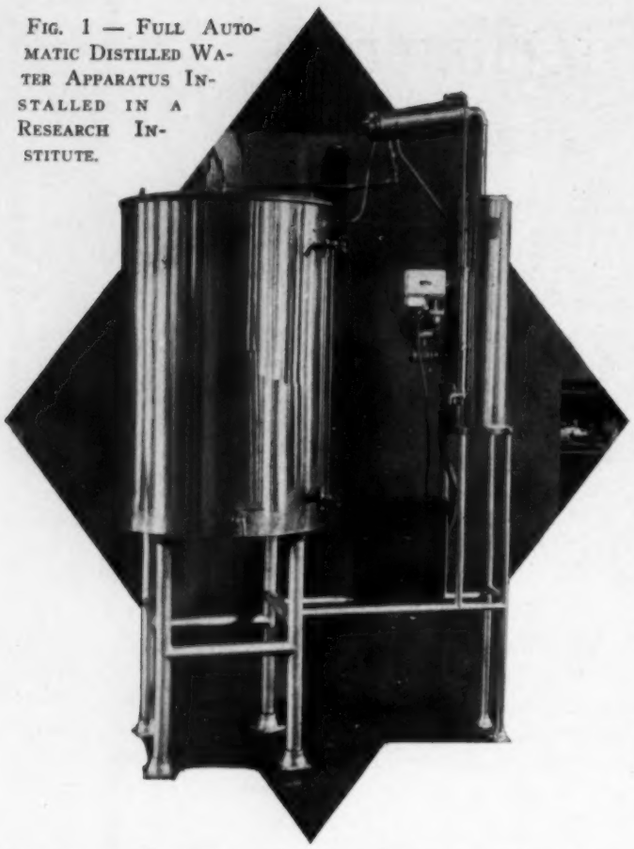


FIG. 1 — FULL AUTOMATIC DISTILLED WATER APPARATUS INSTALLED IN A RESEARCH INSTITUTE.

offset lip on the bodies and prevent, to some extent, the possibility of boiling over or condensation dripping on the floor. The covers are usually arranged, on all but the smaller sizes, to raise or lower simultaneously, with the instrument trays, by the pressing of a foot bar or pedal or treadle device operating a system of levers, and equipped with a checking device. The instrument tray racks are usually so pivoted and attached that the load is balanced, preventing binding and allowing ease of action. The trays are usually constructed of heavy perforated copper coated with block tin.

A waste outlet with strainer should be provided for the larger models, but a drain cock will suffice for the smaller sizes, as a rule. Steam coils for the steam heated types are either secured in the bottom or cast integral with the base. The vent outlet on sizes using a waste should be threaded for pipe of not less than one and one-half inches. The water inlet should have a deflecting elbow. On the small portable electrical sterilizer, the overflow, waste, vent, water and steam connections are usually omitted and a small drain cock, equipped with an insulated handle, provided.

Steam Separator Should Be Installed

The cylindrical or pressure instrument sterilizers using direct steam pressure are rapidly superseding the rectangular non-pressure sterilizers in the operating sterilizing departments of the hospital. This is nothing more than the adaption of the pressure type autoclave sterilizers with the inside arranged with trays for instruments. It is essential with the use of the pressure type of sterilizer that clean steam be used. To accomplish this a steam separator with the proper trap should be installed on the steam line supplying the pressure sterilizer.

Size for Industrial Plant Emergency Room

For the small emergency operating room for the industrial plant, sanitarium, or institution having a first aid room requiring the sterilizing of instruments under steam pressure, the generally accepted size is the 14 inch diameter by 24 inches length, containing (approximately) 3,700 cubic inches. This must be fitted with trays.

Consumption of Steam

The rectangular non-pressure or boiling type instrument sterilizers should be operated at from 35 to 60 pounds steam pressure during the operating cycle and the minimum boiling period of twenty minutes will require the use of steam approximately as follows:

Size, Inches	Steam Consumption Pounds per Hour Max.	Min.
6 x 9 x 18	6	82
8 x 10 x 20	8	100
9 x 12 x 22	10	120
10 x 16 x 24	12	135

With electric heating and a minimum of one inch of water, this sterilizer should have sufficient heating elements to come to a quick boil. An automatic cut-off, and not fuse pins, should be provided which positively disconnects the current should the sterilizer be allowed to boil dry. Electric current consumption with two inches of water based on 20 to 30 minutes at high heat and 15 minutes at medium heat is approximately as follows:

Size, Inches	Max. Watts	Current Consumption KW-Hr. per Period
6 x 8 x 16	1000	1.375
8 x 9 x 18	1200	1.575
9 x 10 x 20	1500	1.875
10 x 12 x 22	2000	2.625
10 x 16 x 24	2500	3.125

Sizes of Instrument Sterilizers

The size of instrument sterilizers recommended for any particular use is as follows:

For the utility, dental, ear, eye, nose and throat, and accident departments, a 16 inch by 8 inch, or 9 inch, by 18 inch

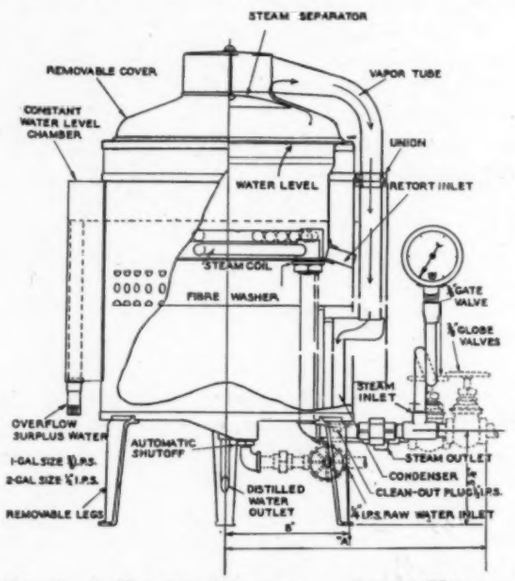
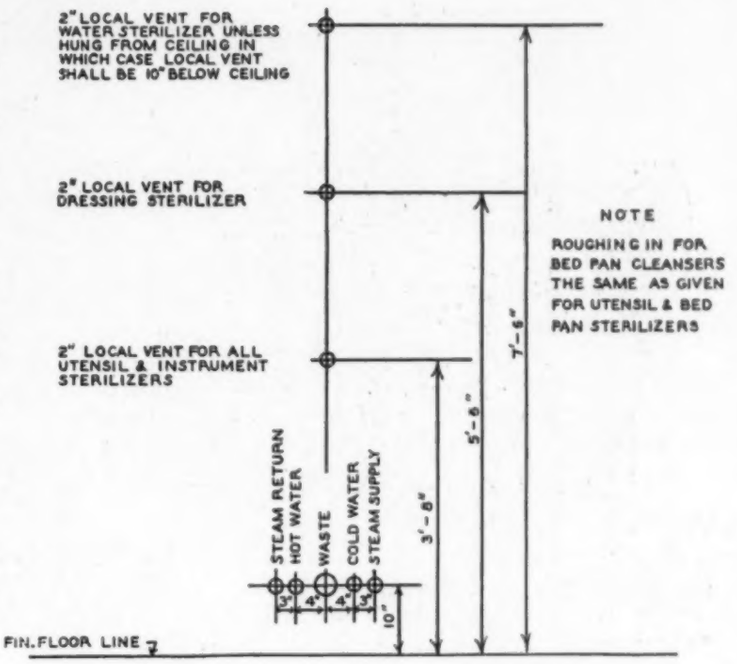


FIG. 2—A TYPICAL DETAIL OF A STEAM HEATED WATER STILL—ONE AND TWO GALLON CAPACITY

FIG. 3—ROUGHING-IN DIMENSIONS FOR STERILIZING EQUIPMENT. NOTE:—THESE MEASUREMENTS DO NOT APPLY TO STERILIZERS LOCATED OVER COUNTERS OR ON SHELVES OR WHEN BUILT IN FLUSH WITH WALL

EQUIPMENT	STEAM PIPES		PLUMBING PIPES			
	SUPPL.	RETURN	LOCAL VENT	WASTE	HOT WATER	COLD WATER
Water Sterilizer.....	1	¾	2	1½	¾	¾
Instrument Sterilizer..	¾	½	2	1½	½	½
Utensil Sterilizer.....	¾	½	2	3	½	½
Bed Pan Sterilizer....						1
Urine and Typhoid Stool Sterilizer.....	¾	½	2	3	½	½
Dressing Sterilizer....	¾	½	2	1½	½	½
Autoclave Sterilizer...						

Note: Where an instrument and a utensil sterilizer are located adjacent to each other on a bracket common to both, the individual pipe services shall be omitted and one service of each kind shall be run for the pair of sterilizers. In such cases where services are combined the pipes shall be made proportionately larger.



is generally selected. However, smaller sizes of the electrically heated instrument sterilizers are procurable, if desired. These sizes are also suitable for the general examination, treatment rooms, urological laboratory, and possibly for utility rooms where the non-pressure or boiling type bedpan sterilizer is used also.

For operating, delivery, or obstetrical department, and some utility rooms, the 22 inch to 24 inch by 12 inch by 10 inch is generally selected, although in some instances a 20 inch by 10 inch by 9 inch would suffice.

The largest tray of the 22 inch by 12 inch by 10 inch will take a large axis tractor forceps assembled, while the small half-length trays will take scissors, haemostats, and the smaller instruments. By removing the three trays, a 13 inch diameter basin may be sterilized.

Where requirements demand, a larger size, the 24 inch by 16 inch by 12 inch is desirable, for it will hold a large number of instruments and, with trays removable, will take several basins. This size is particularly suited to departments where instruments are scrubbed after use, and sterilized before being stored in the cabinets.

Utensil Sterilizers

The rectangular utensil sterilizers are similar in general construction in many ways to the boiling or non-pressure type instrument sterilizers. The utensil sterilizers, where the autoclave is not used for basins or for the average utility room, are often selected 20 inch by 16 inch by 15 inch, although the 20 inch by 20 inch by 24 inch is very often used. This larger size is generally selected in connection with surgical rooms.

The smaller size is frequently used in utility rooms where private rooms prevail and conveniently holds and sterilizes the basins, bowls, pans, water pitchers, and other commonly used utensils. For sterilizing dishes the trays are of smaller design. Water gages, although not always used, are desirable.

The rectangular non-pressure or boiling type utensil sterilizers should be operated at about 60 pounds steam pressure during the operating cycle and the minimum boiling period of twenty minutes, which for the 20 inch by 20 inch by 24 inch size, being most commonly used, would require a maximum consumption between forty and fifty pounds of steam per cycle, or at the rate of 150 pounds of steam per hour, while the 20 inch by 16 inch by 16 inch utensil sterilizing rate is approximately 100 pounds of steam per hour.

Utensil sterilizers of larger sizes are too heavy for the use of nurses operating them. Electric current consumption with four inches of water based on 40 to 60 minutes at high heat and 20 minutes at medium heat is approximately as follows:

SIZE, INCHES	MAX. WATTS	CURRENT CONSUMPTION KW-HR. PER PERIOD
16 x 15 x 20.....	6000	6.0
20 x 20 x 24.....	6000	8.0

Milk and Bottle Pasteurizers

In hospitals a combination milk pasteurizer and bottle sterilizer apparatus, which includes a milk cooler, is used. The pasteurizer heats and maintains the heating temperature to 145 F, or a maximum of 148 F for 30 minutes, followed by rapid cooling, by distributing water evenly over the bottles.

The combination type is usually made as a standard for capacities of 36 up to 288 bottles. For the smaller capacities the carrying basket or bottle racks are reduced in size, generally without reducing overall dimensions of the pasteurizers.

In the larger sizes, having a capacity of 100 eight-ounce bottles or more, a cabinet type with an upper chamber for pasteurizing and sterilizing, and a lower chamber for storage of bottle racks or baskets, is the standard practice.

Pasteurizers are equipped with necessary metal carrying bottle racks or baskets, each usually holding eighteen standard eight-ounce bottles, and are fitted with thermometers mounted on the front of the shells. In some instances special size wide-mouth bottles are used.

Bed Pan Washers and Sterilizers

Formerly the bed pan washers and the bed pan non-pressure sterilizers were of the exposed cylindrical type,

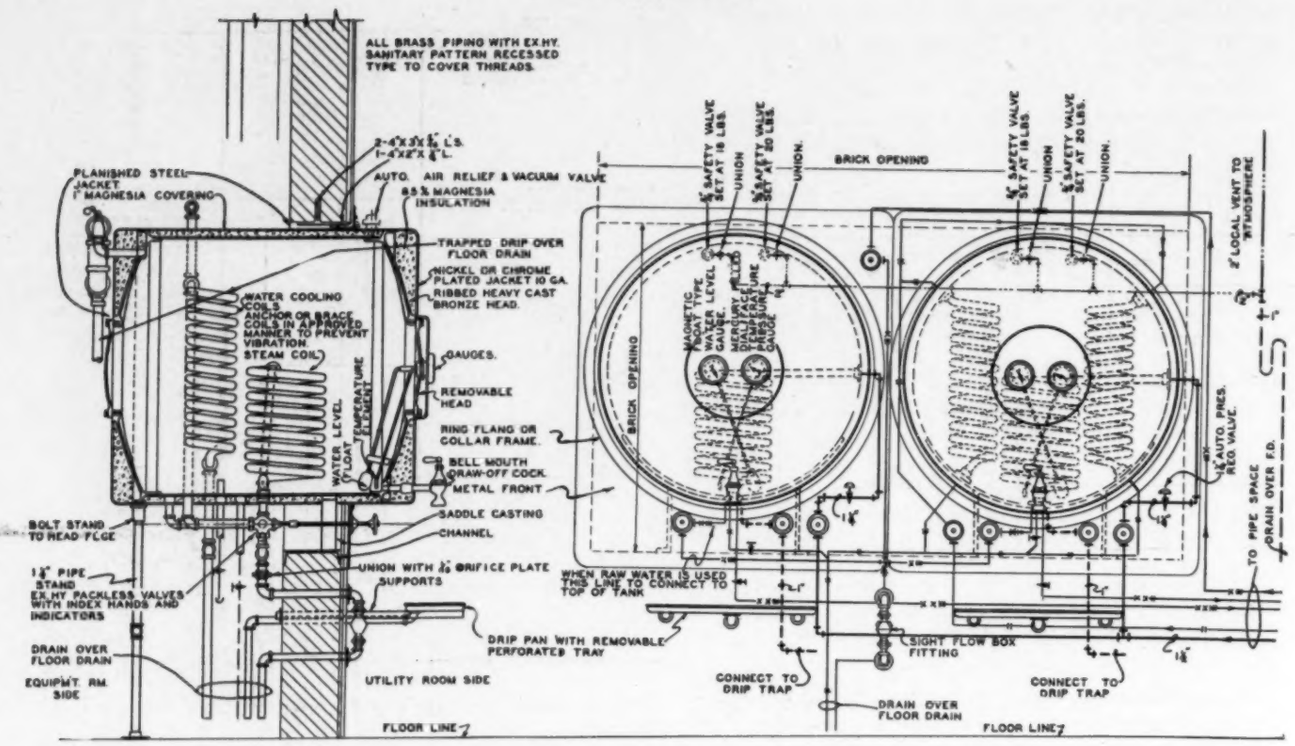

ALL BRASS PIPING WITH EX.HY. SANITARY PATTERN RECESSED TYPE TO COVER THREADS.
PLANISHED STEEL JACKET
1" MAGNESIA COVERING
AUTO. AIR RELIEF & VACUUM VALVE
85% MAGNESIA INSULATION
TRAPPED DRIP OVER FLOOR DRAIN
NICKEL OR CHROME PLATED JACKET 10 GA.
RIBBED HEAVY CAST BRONZE HEAD.
WATER COOLING COILS ANCHOR OR BRACE COILS IN APPROVED MANNER TO PREVENT VIBRATION
STEAM COIL
GAUGES.
REMOVABLE HEAD
RING FLANG OR COLLAR FRAME.
BELL MOUTH DRAW-OFF COCK.
METAL FRONT
SADDLE CASTING
CHANNEL
BOLT STAND TO HEAD FLGE
UNION WITH 1/16 ORIFICE PLATE SUPPORTS
1 1/4" PIPE STAND
EX.HY PACKLESS VALVES WITH INDEX HANDS AND INDICATORS
DRAIN OVER FLOOR DRAIN
EQUIPMT. RM. SIDE
UTILITY ROOM SIDE
FLOOR LINE
DRIP PAN WITH REMOVABLE PERFORATED TRAY
WHEN RAW WATER IS USED THIS LINE TO CONNECT TO TOP OF TANK
BRICK OPENING
BRICK OPENING
3/4" SAFETY VALVE SET AT 15 LBS.
UNION
3/4" SAFETY VALVE SET AT 20 LBS.
UNION
MAGNETIC FLOAT TYPE WATER LEVEL GAUGE
DIAL FACE TEMPERATURE PRESSURE GAUGE
3/4" SAFETY VALVE SET AT 15 LBS.
UNION
3/4" SAFETY VALVE SET AT 20 LBS.
UNION
2" LOCAL VENT TO ATMOSPHERE
1" AUTO. PRES. REG. VALVE.
TO PIPE SPACE DRAIN OVER F.D.
SIGHT FLOW BOX FITTING
CONNECT TO DRIP TRAP
DRAIN OVER FLOOR DRAIN
CONNECT TO DRIP TRAP
FLOOR LINE

FIG. 4—TYPICAL DETAIL OF HORIZONTAL WATER STERILIZERS

Note: Steam coil 20 lin. ft. 1⅛ in. O. D. seamless copper tubing or equivalent. Exterior heavily tinned. Cooling coils to be 36 lin. ft. seamless copper 1⅛ in. tubing or equivalent. Exterior heavily tinned. All exposed piping in finished room side to be nickel or chromium plated. Tanks to have suitable name plates and shall be marked hot or cold as required.

Note: Drawn for 150 gallon capacity. Others similar. 100 gallon to have 1 in. steam and ¾ in. return. Interior of sterilizers to be heavily tinned with pure block tin.

less than 20 inches in diameter with conical bottom. These bed pan washers have the appearance of a hopper with a cover, and are arranged to wash, flush, and clean the bed pan and dispose of the contents through a trap into the soil pipe line at the floor or wall, and in some cases are also equipped as sterilizers.

The bodies are made of heavy gage copper or brass shells with tinned smooth interior surfaces which automatically flush at each operation to prevent adherence. The automatic flushometer type of flush valves is widely used in connection with sprays to flush out waste matter. The interior of the cleansing apparatus is designed with a rack or cradle to receive and positively grip and hold bed pans or urinals of various sizes. Through a foot bar, pedal or treadle arrangement, the nurses apply pressure and raise the cover and also raise and present a cradle or rack adjustable to receive the different sizes of bed pans. Upon releasing the pressure on the foot bar, the cover closes, tilting and lowering the bed pan and automatically emptying all contents, after which the bed pan may then be thoroughly washed. The cover fits into a lip seal and prevents the escape of odors which pass off through a two-inch vent in the rear.

Recessed Construction

Within the last decade there have been developed new types of compact bed pan washers and bed pan non-pressure sterilizers which may be recessed for built-in, semi-concealed construction, or may be exposed. Usually the recessed type requires a depth of approximately eight inches and project in front up to a maximum of about six inches. The construction of the chamber is usually of copper, bronze, nickel, porcelain, enameled finish, or vitreous ware, such as does not stain or discolor from acids. The cover sprays are provided in the interior to flush interior and exterior of bed pans. The built-in type sterilizers will not receive the urinals.

In connection with the sterilizers, it is sometimes demanded by the local public health authorities that the flush-meter valve be located six inches or more above the top rim of the washer. The steam supply connection for the combination bed pan washer and sterilizer is so made and connected so that it reaches the interior surface of the bed pan.

The minimum sizes of connections for bed pan washers and sterilizers are 3-in. soil, ⅜-in. high pressure steam; 1-in. cold water, 2-in. local steam vent, and a 2-in. soil revent; a 1-in. hot water connection is advisable when the washer is used for cleansing pans when oil enemas have been given.

Steam consumption figures for bed pan sterilizers are not available, because they are so very indefinite in operation. Steam, as a rule, is turned into one of these machines for a period of not to exceed 3 minutes, through an opening approximately ⅛ inch in diameter at the maximum.

Water Sterilizers

Water sterilizers are usually designed with a set of two closed reservoirs or tanks, one for cold and one for hot sterile water. Occasionally a single tank or reservoir will suffice.

The construction consists of seamless drawn, pure block tin-lined copper, dome shaped, and heavy brass jacketed shells and heavy dished bronze bottoms. A set of water sterilizers is fitted with a stone water filter

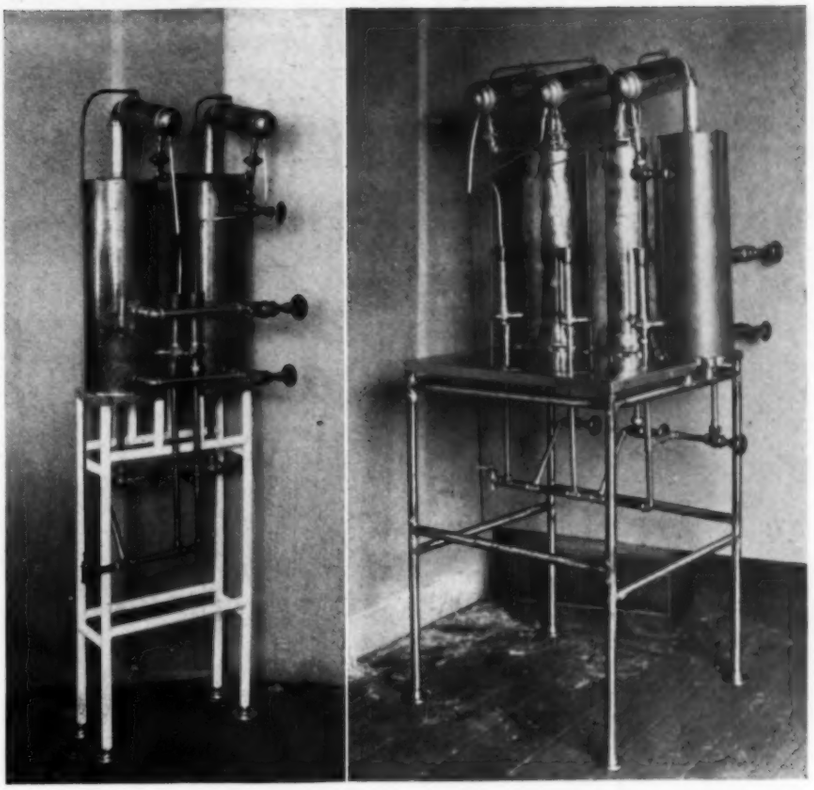


FIG. 5 — LEFT — A DOUBLE-DISTILLED WATER OUTFIT. FIG. 6 — RIGHT — TRIPLE-DISTILLED WATER APPARATUS

enclosed within the seamless brass shell, pure block tin-lined inside and provided with a removable water-tight cover, having a holding screw or bolt.

The usual equipment or trimmings with a set of water sterilizers includes automatic air exhaust and vacuum breaking devices with cotton packed cups, gage glasses or an equivalent water-level indicating device, bell protected draw-off faucets, gages indicating temperature and pressure and heavy duty angle valves, connecting water and waste. If steam heated, steam and drip return valves are a part of the equipment; if gas heated, a gas cock, gas burner, air mixer and piping are included and, when requested, a gas pilot valve.

Both tanks are fitted with steam coils and a cold tank with a cooling coil of block-tin covered copper pipe. The rated capacity of a water sterilizer varies, due to the fact that there is no accepted agreement on this. Some measure the volume of water contained within the limits of the gage glasses, while others measure the capacity of the reservoir from the base of the reservoir to the beginning of the dome-shaped top. Tanks or reservoirs should have the identifying marking "hot" and "cold." Where sterilizers are built in concealed, it is sometimes advisable that insulation of one-half inch to one inch be provided.

Steam Consumption of Water Sterilizers

The steam consumption of water sterilizers varies with the heat loss of the tank shell as well as capacity to heat the water from the average yearly city water main temperature to approximately 260 F at 15 to 20 pounds pressure, maintaining temperature and pressure for a 20-minute period to destroy all forms of bacteriological life.

Size, Gallons	Steam Consumption Pounds per Hour	
	Min.	Max.
6	10	125
10	12	150
15	15	165
25	20	250
35	25	300
50	30	500

Electrical Consumption

Electric current consumption for each water reservoir for heating, based on 60- to 90-minute high heat and 20 minutes medium heat, is approximately as follows:

Size, Gallons	Maximum Watts	Current Consumption KW-Hr. per Period Each Tank
6	3,000	3.5
10	5,000	5.33
15	6,000	7.00
25	10,000	14.16

Horizontal water sterilizers, which the writer assisted in developing, are of recent innovation. Fig. 4 illustrates this type of sterilizer construction. In this construction the water gage glass normally used was omitted and in lieu of it a magnetic float type water level gage was installed to indicate the water level in the sterilizer. The adoption of this water level gage eliminated the trouble previously experienced in the use of vertical type sterilizers where water gage glasses were used, which were not always sterile. This arrangement also included the use of a combined mercury-filled, dial face temperature and pressure gage.

The shell construction of this sterilizer should be made similar to that of other sterilizers except in the larger sizes the tank should be constructed of heavy cold rolled copper or brass shells, riveted and sweated, tinned on the inside, with heavy cast bronze head or equivalent, which should be sweated and tinned.

Every horizontal water sterilizer should have a manhole in one end or the other for access to the interior. The head ends should be hemispherical in shape, except for sterilizers, which would have a heavy bronze plate.

As with other types of sterilizers, the capacities of water sterilizers are debatable, depending upon the economical use of sterilized water, but the following minimum sizes, the writer believes, is the general consensus of opinion:

For one surgeon's office, one 5 or 6-gallon set.

For one emergency or dressing room, one 10-gallon set.

For one major and minor operating room, one 15 to 20-gallon set.

For one delivery room, one 15 to 20-gallon set.

For two major operating rooms, or two delivery rooms, one 25-gallon set.

For groups of rooms, the larger sizes, such as 35, 50, 75, and 100-gallon sets are generally selected.

Five gallons of sterile water are usually ample for each major operation.

Office Building Rental Problem Simplified by Air Conditioning System

VIEW OF PENT HOUSE FAN ROOM

By Ralph E. Phillips*

THE Banks-Huntley office building was constructed for the firm of Banks-Huntley and Company, at 634 South Spring street, which is the financial center of Los Angeles. The building is located on an inside lot 60 ft. wide by 138 ft. deep. The owners selected Messrs. John and Donald B. Parkinson as their architects, L. E. Dixon company, general contractors, and Ralph E. Phillips, mechanical and electrical engineer. The air conditioning contract was awarded to H. S. McClelland company and the heating contract to F. D. Reed company. All the above firms are located in Los Angeles. Donald T. Robbins is the chief engineer.

The building is limit height, twelve floors, mezzanine, basement and sub-basement and is built over the entire ground area for the lower five floors and an interior court for the upper seven floors. The building is almost entirely occupied by brokers, bond houses and law offices. The contract for the building was let without any interior partitions in order to meet the special needs of the various tenants due to their specialized business.

Windows Locked; Building Treated Acoustically

The problem of constructing a building of this type was carefully considered by the owners and architects due to the fact that the building was built on an interior narrow lot and with the limited floor space provided in Los Angeles due to the limit height of 150 ft. maximum and desirable floor space had to be provided. Owing to the business of its tenants, the problem of eliminating outside street noise was also a factor to be considered. It was finally decided that the solution for the difficulties encountered would be to entirely air condition the building and lock the windows, treat the ceilings with acoustical material and build the structure over the entire lot for the lower five floors; this provided natural light only on the street front and rear wall for the first five floors with the upper seven floors having natural light from the interior court. The Banks-Huntley building is the first office building in the far west to be completely air conditioned.

Air Conditioning Divided in Units

Weather conditions during the day both summer and winter in Los Angeles change rapidly within a few hours and therefore it was necessary that the air conditioning system be so divided up in units that the various exposures be taken care of separately to maintain constant conditions throughout the building. Generally the systems are as follows:

1. A separate system for the entire ground floor and mezzanine, which space is occupied by H. J. Barneson and company, brokers.
2. A separate system for the interior loft spaces from the 2nd to 5th floors, inclusive.
3. A separate system for the offices on the front wall of the building.
4. A separate system for the offices on the rear wall of the building.
5. A separate system for the court offices from the 6th to 12th floors, inclusive.
6. A separate system, air washed only, for the basement and sub-basement.
7. A toilet exhaust system.

In computing the capacity of the air conditioning system, it was assumed that the building would be occupied by approximately 1,350 persons.

Apparatus Located Near Center of Load

In order to keep the duct sizes as small as possible, the system was designed to locate these various plants

* Consulting engineer, Los Angeles, Calif.

You'll find some interesting figures in this article on the cost of installation and operation of the air conditioning system in this new Los Angeles office building. The author—consulting engineer on the job—describes the air conditioning system which he says made the rental problem an easy one and allowed the building to demand rentals in keeping with the numerous advantages of soundproof, completely air conditioned structures.

as near to the center of load as possible and therefore the apparatus for the basement, ground floor and interior of loft floors were located in the machine room in the basement and apparatus for the front and rear walls located on the fifth floor level and the plant for the court walls located in the roof pent house.

Vacuum Heating System Installed

In addition to the air conditioning system, there was installed throughout the building a two-pipe vacuum return heating system so that the building could be heated before and after office hours without running the air conditioning system and also to provide individual heat control for each office.

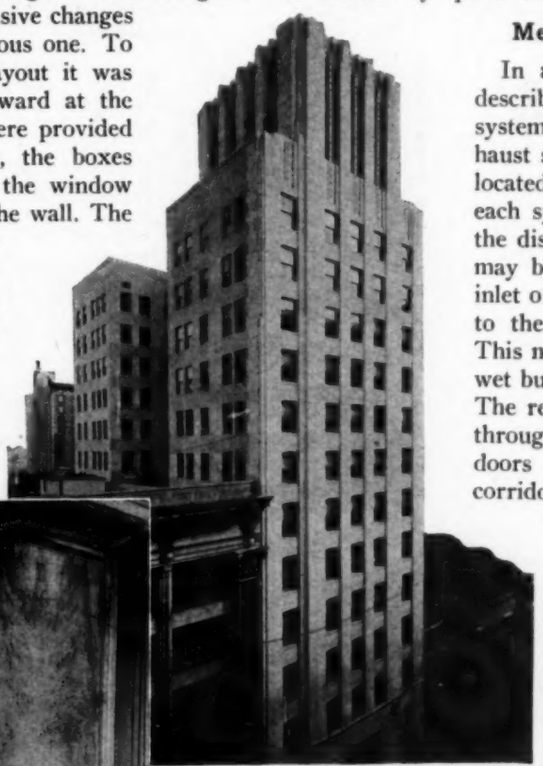
The building being designed with all floors left open and the possibility of partitions being placed at almost any place, the problem of introducing and exhausting the air without the necessity of extensive changes to fit partition layout, was a serious one. To provide flexibility in partition layout it was decided to introduce the air upward at the window sills. Window boxes were provided under practically every window, the boxes being the length and height of the window sill and extending 8½ in. from the wall. The finish of these boxes is walnut with bronze grilles. The supply duct was brought into these boxes from below the floor and transformed in shape to a long narrow outlet just below the grille in the top of the box, giving the air a high velocity upward, causing complete diffusion above the breathing line.

Detail of Concealed Radiator and Supply Air Inlet Enclosure Box

In this window box is also located the concealed fin type direct radiator with inlet grille in the base of the box and outlet at top. The heating and ventilating sections of this box are entirely separate and manual control is provided for both the steam and air flow. On the loft floors, where large open areas without windows are located, supply grilles were placed in the walls near the ceiling along both sides of these spaces at intervals of approximately 10 ft., so that with any arrangement of partitions each office would be provided with supply air. All supply air to the various systems is heated by indirect heating stacks at the apparatus thermostatically controlled by pilot room and duct thermostats.

Mechanical Exhaust Systems

In addition to the supply systems described above the various individual systems each have a mechanical exhaust system. These exhaust fans are located adjacent to the supply fans for each system and are so arranged that the discharge from these exhaust fans may be automatically returned to the inlet of the dehumidifiers or exhausted to the outside or partially returned. This method of control is regulated by wet bulb thermostats from the outside. The return air from the offices passes through louvres over the corridor doors and is circulated through the corridors to three exhaust registers on each floor in the corridor walls.

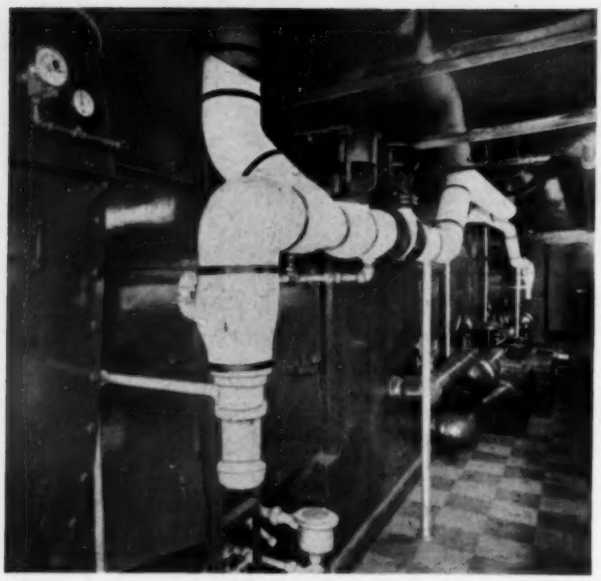


Front Facade and North Wall of Building Showing Interior Court

Coolers for Dehumidifiers on Three Different Levels

The refrigerating plant is located in the machine room in the basement and consists of one 120-ton unit and one 60-ton unit, motor driven. The compressors are automatically controlled by a switch.

The coolers consist of three separate units. The necessity of the three separate coolers was due to the fact that the dehumidifiers are on three different levels



Fifth Floor Fan Room

and by separating these levels on individual coolers, the system is operated on a balanced head and thereby eliminates the difficulties of serving dehumidifiers on different levels from one cooler. It also provides a more flexible control of water temperature.

The water is circulated from these coolers by centrifugal pumps located adjacent to each dehumidifier and for each dehumidifier there is an automatic three-way valve which automatically maintains the proper temperature of the water by re-circulating the water within the dehumidifier or using low temperature water or mixing; the three-way valves are controlled by wet bulb thermostats in the return ducts.

The Cooling Tower

The problem of cooling the condensing water for the refrigerating plant necessitated the use of a forced draft cooling tower in the pent house, the architecture of the building prohibiting the use of a gravity tower. This forced draft cooling tower consists of a chamber 14 ft. 6 in. by 15 ft. by 32 ft. 6 in. high; air is supplied to this cooling tower with four 72 in. disc fans located at the base, discharging the air vertically through eliminators to the outside. Supply air to these disc fans is obtained through louvres in openings in the pent house walls. The water is distributed over the area of the cooling tower by nozzles and falls through a series of six screens.

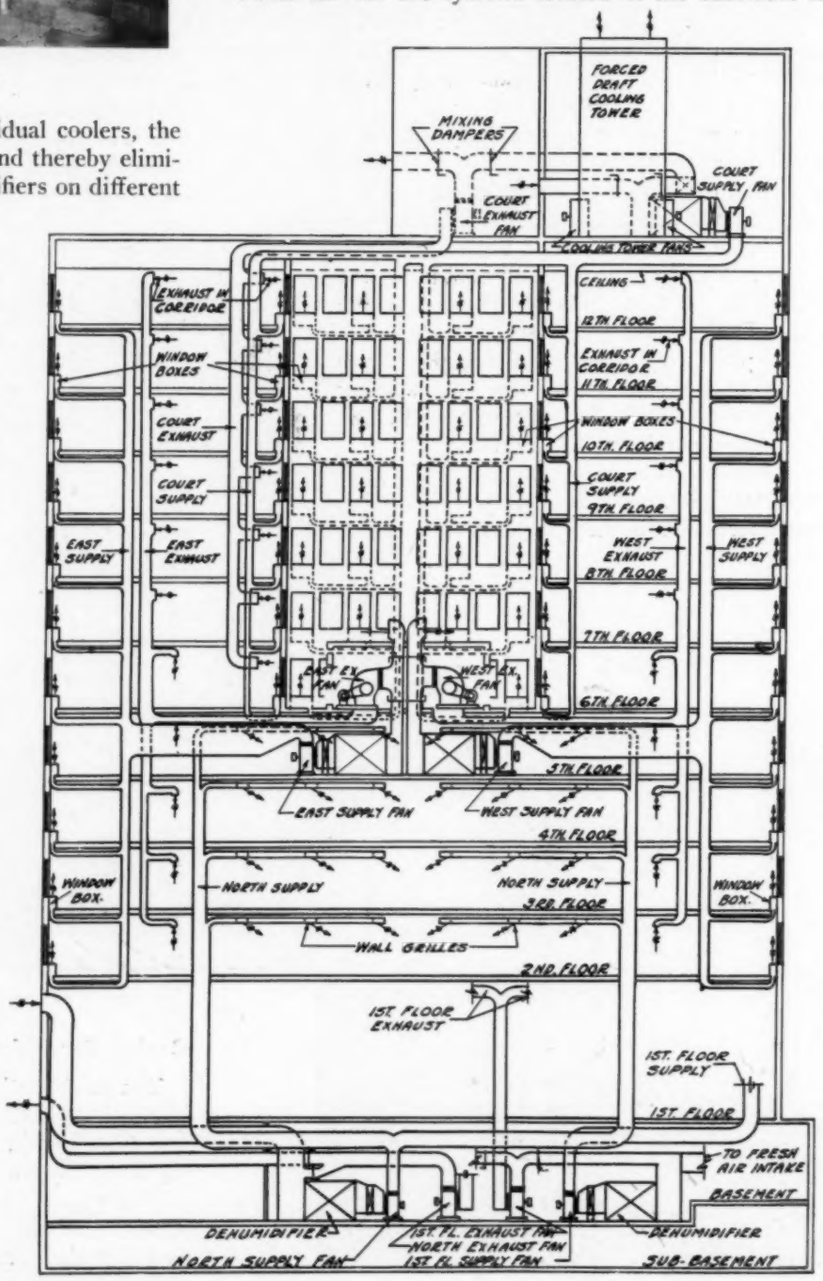
Atmospheric Conditions Maintained

The air conditioning system was designed to maintain inside dry bulb temperature of 75 F with 55 per cent relative humidity when the outside temperature is 95 F dry bulb and 70 F wet bulb during the summer months, and during the fall, spring and winter periods the system is designed to maintain 72 F dry bulb and 60 F wet bulb, regardless of outside conditions.

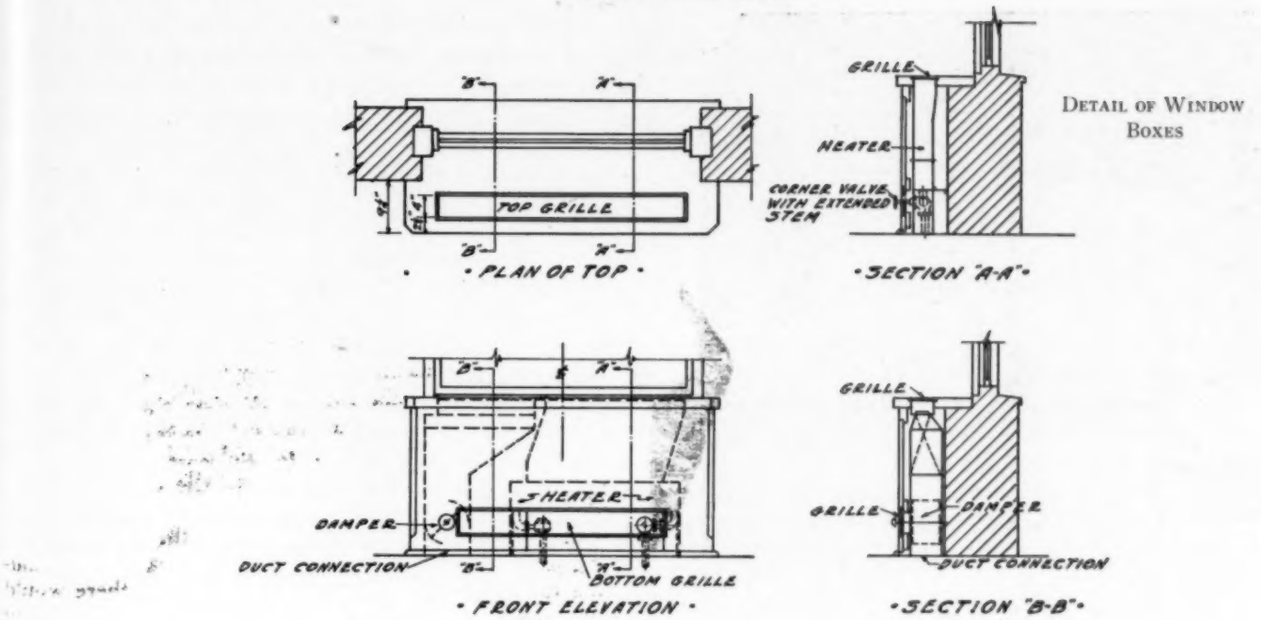
The minimum temperature of air leaving the window boxes in summer is 55 F and the maximum during winter is 70 F. The total cubic feet of supply air, including the air washed basement system, is 90,400 c.f.m. and the total cubic feet of exhaust return air is 90,700 c.f.m. The toilet exhaust fan has a capacity of 7,890 c.f.m. Each of the four disc fans on the cooling tower have a capacity of 33,800 c.f.m.

Fresh Air Intakes

Fresh air for the systems located in the basement is



Longitudinal Section of Building



Detail of Window Boxes

obtained through louvred openings on the rear wall of the building at the third floor level and the exhaust discharge is through louvred openings at the rear wall at the ground level. Fresh air for the systems located on the fifth floor and in the pent house is obtained through louvred openings at the apparatus and the exhaust is discharged on the opposite side of the building. No method of mechanically filtering the air or ozone treatment has been employed. Mesh screens, however, are provided in back of all air intakes and discharges.

Fan Capacities and Pressures

The compressors used are of the direct-connected, rotary type using methyl chloride as a refrigerant. The motors for the compressors are variable speed, slip ring type, 3 phase, 220 v., 50 cycle, 150 hp. for the 120-ton unit, and 75 hp. for the 60-ton unit, the motors operating at a maximum speed of 985 r.p.m.

The control equipment is arranged so that the compressor speed may be manually set and the automatic control will stop and start the compressors as the water temperature demands, bringing the compressors up to the speed set. The fans are of the multivane type, belt driven with multiple V-type short drive belts on fibre V-cut sheaves. The quantity of air handled is given in the following table:

Systems	C.F.M. Supply	C.F.M. Exhaust
Ground floor and mezzanine	22,000	21,250
Interior loft spaces	12,700	12,300
Offices on front wall	15,200	16,400
Offices on rear wall	14,000	14,000
Offices on court	15,200	16,400
Basement (washed only)	11,500	10,400
Toilet	.....	7,890

The static pressures from actual tests on the supply fans vary from 1 in. to 1.4 in. and on the exhaust return fans from 0.45 to 0.7. The total horsepower on the supply fan motors is 45 hp. and the total horsepower on the exhaust return fan motors is 24 hp. The toilet exhaust is 3 hp. and the total motor horsepower for the cooling tower is 30. All dehumidifiers are of the double spray type.

The coolers are rectangular cast steel units with vertical tubes, the refrigerant passing through the tubes and the water on the outside. The coolers were designed for 13 sq. ft. of tube surface per ton of refrigeration with combined capacity to cool 725 g.p.m. from 48 to 42 F. The condenser water pump, which is located in the machine room, has a capacity of 600 g.p.m., against a combined friction and static head of 100 ft.

All heating stacks at the supply fan discharges were constructed of fin type units with capacity to raise the temperature from 30 to 80 F.

Velocities in Ducts

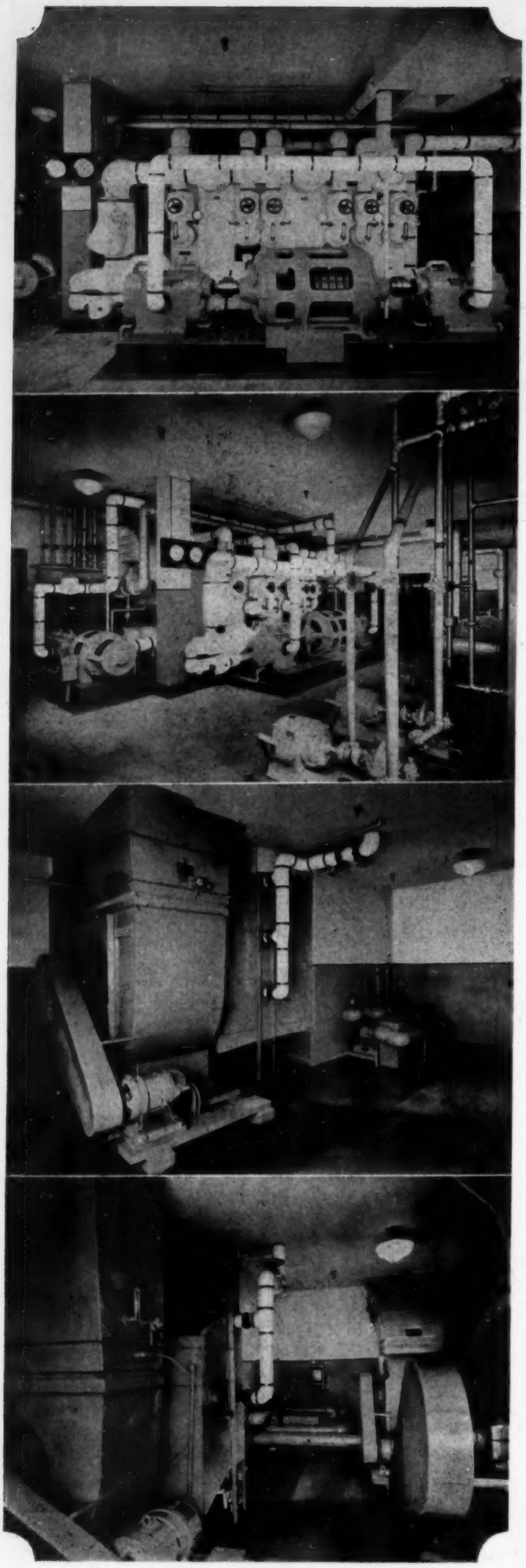
Galvanized iron was used for all duct work of standard gages for various size ducts and the velocity in the ducts reduced from 1,500 ft. velocity at the fans to 700 ft. at the window boxes. The duct section at the window boxes is transformed to a rectangular nozzle so that the inertia of the air would carry it at high velocity adjacent to the windows and diffuse above the breathing zone with room air.

Indicating Instrument in Engineer's Office

There has been installed throughout the building a wet and dry bulb indicating instrument which indicates in the engineer's office the conditions in the rooms on each of the supply systems, which makes it unnecessary for the operating engineer to leave the machine room except for customary maintenance to the equipment throughout the building.

Cost of Installing the Air Conditioning System

The total cost of the air conditioning plant, including the toilet exhaust and the air washed system for the basement and sub-basement was approximately $78,000.00, which did not include the heating system. Based on the rentable floor area of 62,365 sq. ft. this is approximately $1.25 per sq. ft., it being kept in mind that this cost also includes the air washed system for the basement and sub-basement and toilet exhaust.



Top to Bottom

Front Elevation of 120-Ton Compressor, Three Water Coolers and Valve Control of Cooling Water

General View of Refrigerating Machine Room Showing 120-Ton and 60-Ton Refrigerating Unit, Condenser and Liquid Receiver in Background

View of Basement Fan Room

View of Basement Fan Room

The cost of the air conditioning and ventilating system, based on population of the building, amounts to approximately $57.75 per person. Basing the cost of the air conditioning system on the total volume of the building, which is 1,306,000 cu. ft., the cost per cu. ft. of building is approximately 6c.

It is difficult to estimate the cost of the air conditioning plant per office, but, assuming the area of the building as applied to a standard office building, there would be approximately 290 offices, which would give a unit cost per office of $268.00 for the air conditioning and ventilating system.

Comparing the Banks-Huntley building with structures that might be erected in the middle northwest and the north eastern sections of the country, it would seem that the unit costs for constructing air conditioning systems would be comparable to that which could be obtained in Los Angeles, however, air conditioning systems that would be constructed in Arizona, Texas and Louisiana, would require more refrigeration and air volume and from our experience at least 15 per cent should be added to the cost of systems installed in those climates.

The Cost of Operation

The cost of operation of the air conditioning system in the Banks-Huntley building is $0.011 per sq. ft. of rentable floor area per month during the summer months when refrigeration is in use and $0.004 per sq. ft. of rentable floor area per month during such periods of the year when the refrigeration is not in use but all fans and dehumidifiers are in operation. These costs do not include make-up on refrigerant gas, lubrication or maintenance of machinery, nor do they include steam condensed by the heating stacks at the fans.

Due to the automatic control of the entire system, the addition of one man to the engineering crew is all that can be charged to the air conditioning system.

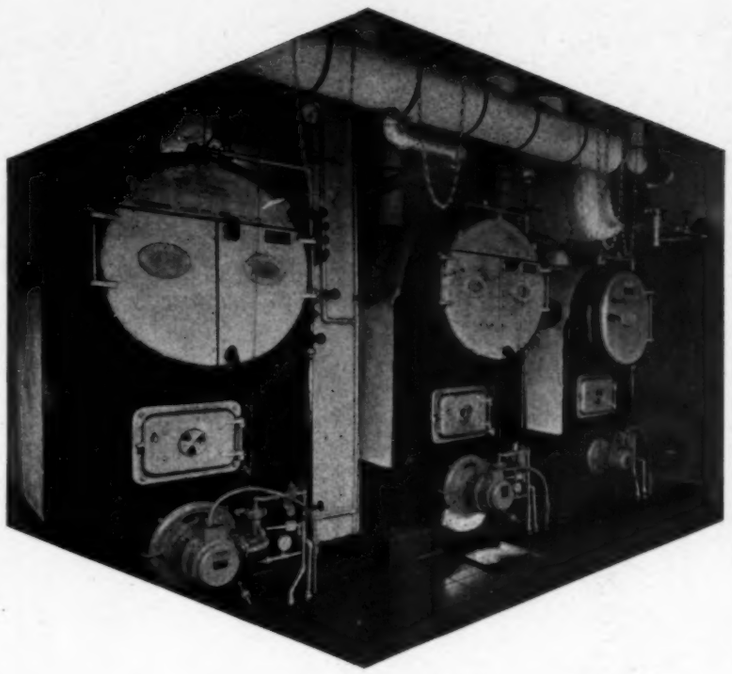
Advantages of Showing Tenants Air Conditioning System

A big problem that the air conditioning engineer faces in equipping entire buildings with air conditioning systems by mechanically introducing the air and locking the windows, is the psychological effect on the occupants of the building. This very soon may be overcome, however, if the systems operate or function properly; a good method is to furnish thermometers in each office so that the occupants may ascertain the temperatures in their rooms for themselves.

Nicely finished fan rooms and machine rooms are a great help so that the tenants of the building may visit these portions and see for themselves the extent of the air conditioning system to provide clean, fresh and

cooled air for their comfort. This method has entirely eliminated such difficulties with the Banks-Huntley building.

Unquestionably this difficulty will be lessened as the people throughout the country become accustomed to the inevitable design of modern office buildings, whereby all windows will be locked and air conditioned. It is a general consensus of opinion of those who have worked in offices where the street noise has been entirely eliminated, that the average efficiency of the occupants is considerably increased and concentration on problems involved in their own business is made easier.



View of Boiler Room

The advantages of sealing a building are obvious from a cleaning standpoint. Practically no outside dust enters the building at any time, and it has been found a very simple matter from an operating standpoint to clean the building.

Climatic conditions in Los Angeles usually do not warrant the use of refrigeration except during the summer and early fall, due to the fact that both the wet and dry bulb temperatures are low enough outside so that all that is required when refrigeration is not necessary is to wash and heat the air in order to maintain comfortable temperatures and relative humidities in the building; therefore, the use of a separate exhaust fan as described has many advantages inasmuch as return air can be entirely or partially wasted and outside air introduced in the building.

It has been found in the Banks-Huntley building that the advertisement of soundproof, air cooled offices makes the rental problem an easy one and also allowed that building to demand rentals which are among the highest in the city.

The Factors in Air Conditioning for Human Comfort

QUESTION: We recently have seen the statement that what is termed "crowd poisoning," CO_2 and lack of oxygen in air are negligible factors so far as human health and comfort are concerned, and that the important factors are temperature, air motion and relative humidity.

Do air conditioning engineers endorse this theory, and if so, where may scientific data be procured on which this belief is based?—*A Subscriber.*

Answer: The theory of crowd poisoning has been largely abandoned. Occupants of buildings do discharge CO_2 into the air and abstract oxygen. These factors are, however, very seldom of any importance. One would have to take quite extreme cases in order to cite examples of any detrimental physiological effects from CO_2 and lack of oxygen. One extreme case of such detrimental effects from CO_2 came from the leaking of CO_2 from a refrigerator. In another case a physician kept visitors out of a hospital room because of the possible depletion of oxygen. Oxygen was administered to the patient from time to time.

The main requirement, so far as air conditioning is concerned is to maintain a normal rate of heat loss from the human body. If the rate of heat loss is much above normal or much below normal the occupant will be uncomfortable. The factors that affect the rate of heat loss and, consequently, the comfort of the occupant are air motion, relative humidity and temperature.

Factors which have nothing to do with the rate of heat loss, but which are desirable, are absence of odors and absence of dust which essentially, are the same thing, since it is the impingement of microscopic dust particles on the olfactory nerves which is responsible for our sense of smell.

Still another factor is the ionization of air. Few engineers claim to understand *all* about the ionization of air and its possible benefits and for this reason this factor is in many cases ignored. There is a theory that when air strikes highly heated surfaces or goes through long metal ducts that it loses something which, for want of a better name, has been called ionization. This is aside from your question, however.

In order to answer this question as concisely as possible, it should be stated that the practice of the majority of the air conditioning engineers in this country is based upon the belief that temperature, motion and relative humidity are the major factors in air conditioning and that so-called crowd poisoning, the discharge of CO_2 in the air or lack of oxygen, except in very rare cases, may be ignored.

This belief is based upon tests that have been conducted for many years at the research laboratory of the *A. S. H. V. E.*, data on which may be found in the *A. S. H. V. E. Guide.* The practice of air conditioning engineers is also based on tests conducted by other research workers, physicians and physiologists, of course.

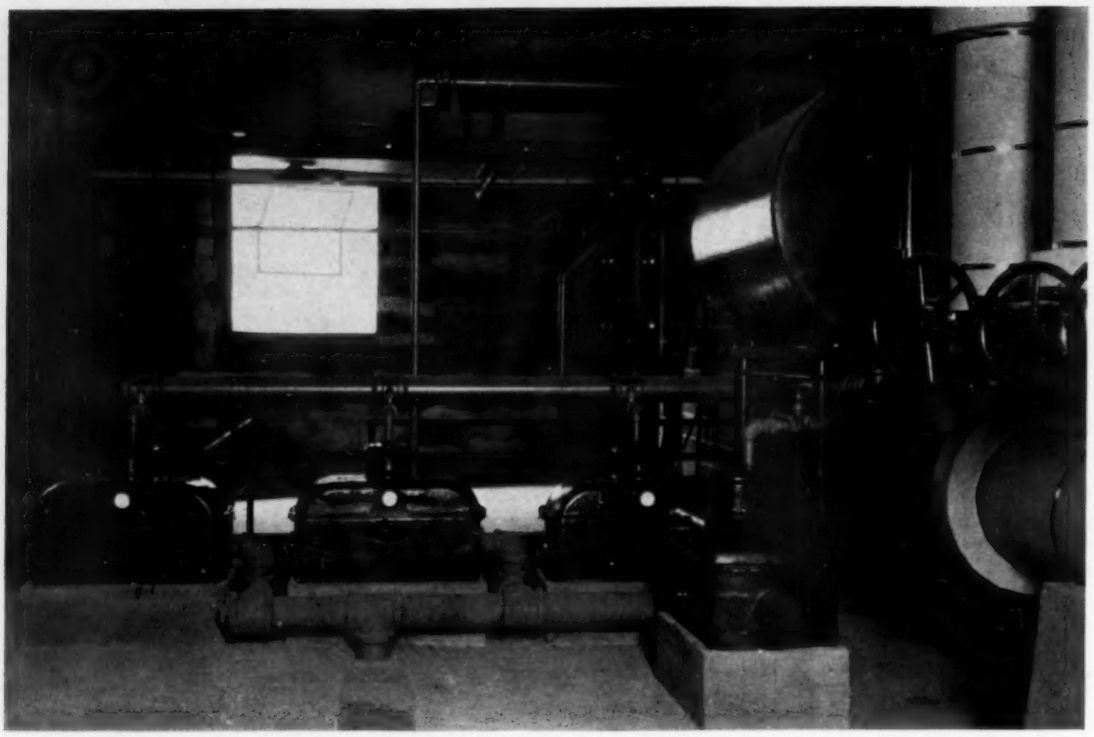


FIG. 1—FOUR CONDENSATION METERS HOOKED UP IN TANDEM TO MEASURE THE CONDENSATE FROM A LARGE RECEIVING TANK. THE MAXIMUM LOAD IS 23,000 LB PER HOUR

Use of Condensation Meters in Heating Systems

By B. M. Conaty*

WITHIN the field of district heating, the application of the condensation meter is quite generally understood for it is probable that the bulk of the steam sold is billed on condensation meter readings. In this field the results obtained by its use in accuracy and dependability compare favorably with those common to other fields of metering. However, outside of the district heating utility, in industrial plants and institutions the desire for metering steam consumption exists but is not always satisfied due perhaps to the lack of information on the use of this simple device.

In general, the condensation meter, as the name indicates, meters steam consumed in a heating system by measuring the condensation discharged from the system. It is applicable to any installation where the condensed steam can be collected at a central point and passed through the meter before being discharged into the return line or sewer.

Dumping Type

Two types commonly used are differentiated as the dumping and the rotating meters. The dumping type consists of two buckets so mounted on a shaft that the buckets alternately fill and empty a predetermined quantity of condensation, each compartment actuating a counter mechanism as it dumps. The counter automatically converts the reading into pounds of condensation or pounds of steam consumed.

The Rotary Meter

The rotary meter consists of a series of compartments mounted upon a hollow rotating shaft through which condensation enters and is discharged into the meter compartments. The successive filling of the compartments causes the meter to rotate and discharge the water from the rotor. Each revolution of the rotor discharges a given weight of condensation which is recorded on the counter in pounds.

Use of Surge Tank

The installation of either type of meter, while simple, requires careful adherence to two particular conditions. The inlet of the meter must be so connected as to avoid any appreciable head of water coming on it through sudden surges of steam condensed in the system and the outlet must be of ample size and proper grading to insure quick removal from the meter case of the discharge from

* American District Steam Company, North Tonawanda, N. Y.

the buckets or rotor. Appreciable pressure on the inlet or accumulation of water in the meter destroys the accuracy.

On a system where sudden surges of condensation are probable, a storage or surge tank should be provided to even the flow through the meter. Such a condensation receiver is also necessary where a vacuum pump is used. The recommended size of such a receiver may be obtained from the following table.

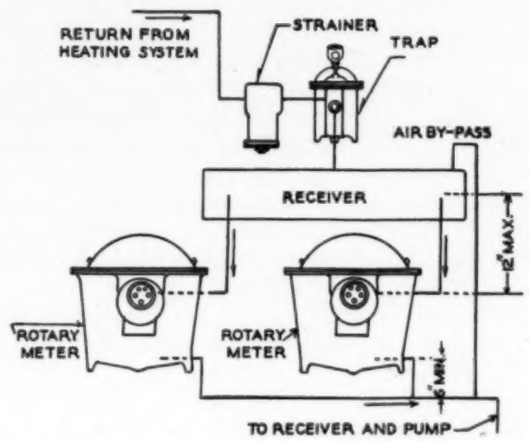


Fig. 2—Rotary Meter Installation in Parallel with a Receiver—Vacuum System

Condensate Receiver Sizes

Equivalent Direct Radiation—Sq. Ft.	Capacity of Receiver—Cu. Ft.
5,000	4
7,500	5
10,000	7
12,500	9
15,000	10
17,500	12
20,000	14
25,000	17
30,000	21
35,000	24
40,000	28
45,000	31

Two Meters Often Desirable

Where large meter capacities are required it is usually more desirable to use two or more medium sized meters than one large one. The smaller meters can be so connected that the low flows encountered during mild weather, which might represent a very small percentage of the rated capacity of a large meter, may be passed through a single meter and operate it at sufficient speed to insure more accurate results. There is also the added advantage of duplicate units which facilitates ease of handling and servicing. In the use of multiple units it is, of course, necessary to use a storage tank or manifold arrangement which distributes the load approximately equally.

Since the best operating results are obtainable with a uniform flow of condensation to the meter, consideration should be given to the type of trap installed with the meter. Intermittent flow should be avoided as much as possible; a continuous flow trap is desirable which should, of course, be protected by a water strainer on the inlet line.

The temperature of the water coming to the condensation meter should be as low as reasonably possible, for two reasons. In the first place the heat in the water is valuable and as much as possible should be utilized. In the second place, the meter functions more satisfactorily at a temperature of 140 F or less than it does at higher figures. Both of these requirements can be most readily satisfied by the use of an economizer arrangement such as is illustrated in Fig. 3. A small tube heater is installed so that the condensation passing through the tubes gives up its heat to water surrounding the tubes and flowing from the economizer to the building hot water supply heater. The tube area of economizers for a given installation have been worked out as follows:

Radiation Sq. Ft.	Steam Consumption Lb. per Year	Heating Surface in Economizer—Sq. Ft.
170	100,000	4
330	200,000	6
500	300,000	8
830	500,000	12
1,250	750,000	14
1,670	1,000,000	15
2,500	1,500,000	25
5,000	3,000,000	60
8,330	5,000,000	100
13,330	7,000,000	150
25,000	15,000,000	250

Condensation meters are rated in pounds per hour and like other similar devices, must be sized rather carefully. The best performance is usually obtained between 10 per cent and 100 per cent of rated capacity. In sizing the meter for a particular installation the condensation is estimated at ¼ to 1/3 of a pound per square foot of radiation per hour.

Accuracy of Meters

The experience in the district heating field presents conclusive evidence as to the actual performance of the meters. From the records of 23 large district heating companies operating in the neighborhood of ten thousand meters, there is available the percentage of total steam sold per year which has to be estimated due to failure of meters. The individual records range from 0.1 per cent to 3 per cent and the average of the 23 companies is less than 1 per cent.

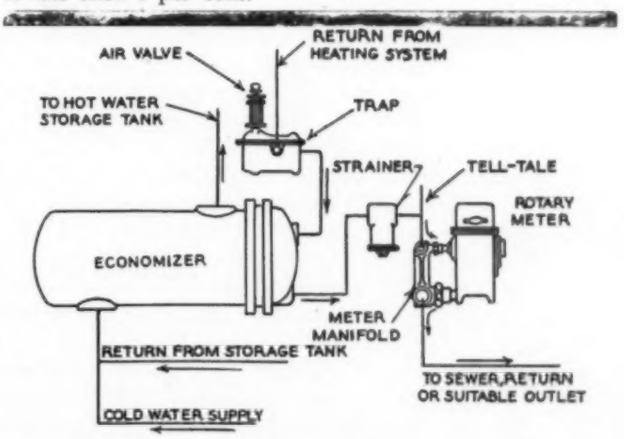


Fig. 3—Economizer Installation with Rotary Meter —Gravity System

Attention Necessary

In the use of meter equipment, it is desirable to know rather exactly the amount of attention required to obtain dependable and continuous records. Specific information on this phase of the matter is available from the practices followed by the heating utilities. They commonly read the meters for billing purposes once a month but their experience indicates that this is not sufficient to note and eliminate interruptions in the meter record. It is their common practice to read the meters for observation purposes weekly in order to catch faulty meter operation and thereby reduce the necessary estimating of consumption to a minimum. It should be noted, however, that this practice of weekly reading is carried on in order that their men may inspect the customer's premises frequently enough to be aware of alterations made to the system, condensation leaks or other conditions of decided interest to the operating company.

In some cases these weekly readings are recorded in curve form plotted on the same sheet as a temperature curve. The comparison of these curves is an excellent indication of faulty meter operation or other difficulty. Appreciable deviation from the form of the temperature curve serves as a warning to the observers, that all is not well in the system, and results in an inspection to determine that all of the condenation is reaching the meter and that the meter is registering correctly.

Annual Overhaul

Proper and continuous operation of mechanical devices is insured by a regular and systematic service procedure. Among the large operators of condensation meters the usual practice is to thoroughly clean, overhaul and test annually. This is a particularly desirable practice where, as is usually the case on heating systems, the meters are idle during the summer months.

The cost of this meter servicing and maintenance is found to range from two to ten dollars per meter per year. These costs, of course, cover large numbers of meters but are in all probability fairly representative of most meter installations for while the heating companies have many meters to care for, they are handicapped by having the individual units located in widely separated locations. The initial cost of the meters ranges from $27.00 to $80.00 per 1,000 pounds per hour of capacity, depending on the size of the unit. These figures, together with the maintenance costs given above, make the annual cost of operation quite low.

On this basis it is obvious that the cost of maintaining complete metering equipment in a group of buildings would not be excessive. When this is considered in connection with the value of records obtained and the possible economies effected by their intelligent application, the reasons for the more general interest in condensation meters is understood.

Refrigerators for Heating

ACCORDING to a report by the consul at Milan, Italy, Homer Brett, which has been made public by the Department of Commerce, the use of refrigerating machines to heat dwellings has been advocated in Italy.

At the last *International Conference of the Refrigerating Industry* in Brussels, Professor E. Guarini of Milan delivered a lecture in which he discussed some startling possibilities. The title of this lecture was "The Refrigerating Machine as a Heat Pump for Warming Dwellings."

Proposed by Lord Kelvin

At first sight it may appear strange that refrigerating machines can be used for heating purposes, yet the idea was put forth by Lord Kelvin in 1852. A refrigerating machine pumps heat out of the body or the atmosphere which it desires to cool to 0 degrees Centigrade or less, and ejects it into the condenser at a temperature of 20 to 25 degrees, adding to the heat extracted the calorific equivalent of the energy used in driving the machine.

The quality of useful heat per kilowatt hour obtainable with refrigerating apparatus depends upon the power of the machine and upon the difference in the levels of temperature, being greater as the machine is more powerful and diminishing when the temperature change between the evaporator and the condenser augments.

By the suggested process, heat may be drawn either from the surrounding air or from water. With air it is better to use a great volume to be reduced only slightly in temperature. The economy of the system lies in keeping the evaporator and condenser as low as possible and this would not exceed 20 or, at the most, 25 deg. C.

In order to use the same machine for cooling a house in summer and heating it in winter a new technique must be developed for low temperature heating; that is, from 20 to 25 degrees Centigrade instead of 80 to 90 degrees, as used in present methods, reducing as much as possible the jump in temperature between the evaporator and condenser.

Under such conditions, extracting heat from the external air or from water one obtains from 1 kilowatt hour from 3,000 to 10,000 calories, of which 864 comes from the electric force and the remainder comes from the surrounding atmosphere, heated, as everything is really heated, by the sun.

Practically, in Italy, for heating dwellings with refrigerating apparatus one can count upon 4,000 calories per kilowatt hour; Professor Guarini calculates that under some circumstances electric refrigerator heating may be cheaper than any other means.

It is considered that the problem has importance for Italy, because with the adoption of electric heating, the nation's bill for imported coal could be reduced and also has importance in that a market necessarily at a low price could be developed for current in hours of low consumption when heat could be accumulated in tanks of water, properly insulated, to be drawn upon during all hours of the day.

Professor Guarini has been advocating the adoption of this system for several years but there is as yet no indication that the practical interest of investors has been aroused.—(Copied from the Consul's report to the Department of Commerce by P. H. McCarthy.)

The System Explained

By H. J. Macintire*

Lord Kelvin's "warming engine" has been of interest since its presentation in 1852. In principle it is the so-called reversed engine or refrigeration cycle whereby heat is absorbed from the cold body (the refrigerator) and is rejected to the warm body (the condenser) and mechanical power is supplied to make the cycle possible. The theoretical cycle can be understood clearly from the following:

The Direct Cycle

The ideal engine cycle is called the Carnot cycle, first proposed by Lieut. Sadi Carnot in 1824, and shown in Figs. 1, 2 and 3. In this ideal engine cycle the cylinder walls and piston are considered to be non-conductors of heat and it is understood that there is no friction. The cylinder head is a good conductor. A working medium is used in the cylinder such as air, steam, or ammonia.

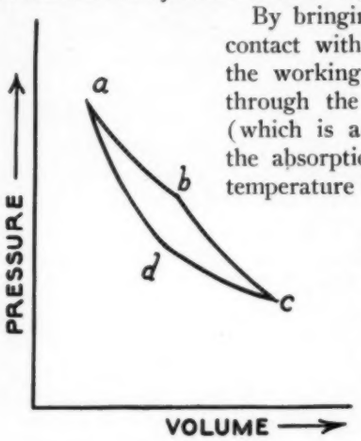


FIG. 1

By bringing the cylinder head in contact with the source of heat S the working medium absorbs heat through the head of the cylinder (which is a good conductor) and the absorption of heat at constant temperature is shown by an increase of volume along the line *ab* in Fig. 1, and the amount of heat absorbed is shown by the area *abef* in Fig. 2.

The cylinder is then conceived to rest on the insulated plate I of Fig. 3 and further expansion of the working medium adiabatically is obtained along the line *bc* and the point *c* represents the maximum increase of volume and the lowest temperature of the working medium possible under the conditions existing in the problem. As no further increase of volume is possible, the cycle must be closed by the rejection of heat along the constant temperature line *cd* wherein the cylinder head is in contact with the refrigerator R and the adiabatic compression line *da* with the cylinder head again in contact with I and the work of compression being done by the inertia of the flywheel or its equivalent.

The external work performed in the cycle is given by the area *abcd* in Fig. 1 in ft. lb. and by the area *abcd* in Fig. 2 in Btu. The heat supplied to the working medium in Btu is given by the area *abef* of Fig. 2, and the heat rejected in Btu at the lower temperature (T_2) is given by the area *dcef*. The efficiency of the cycle is given by the expression $\frac{T_1 - T_2}{T_1}$, so that in order to increase the efficiency the absolute initial temperature T_1 must be increased or the refrigerator temperature T_2 (in F absolute) decreased. The efficiency of the cycle is also given by the expression $\frac{Q_1 - Q_2}{Q_1}$ where Q_1 is the heat absorbed from the source and Q_2 is the heat rejected to the refrigerator *in the direct cycle* and Q_1 and Q_2 are the heat rejected to the source (the hot body) and absorbed from the refrigerator (the cold body) respectively *in the reversed cycle*. $Q_1 - Q_2$ is the work performed in the direct cycle in heat units and if the work is expressed in foot pounds as it usually is then the expression AW or $\frac{\text{work}}{778}$ is the work performed in heat units (Btu).

Reversed Carnot Refrigerating Cycle

The ideal refrigerating cycle is a reversed Carnot wherein heat is absorbed by the working medium at the lower absolute temperature T_2 and is rejected at the upper absolute temperature T_1 and the work performed is equal to the area of the enclosed area *abcd*.

For example, liquid ammonia in a pipe coil absorbs heat and boils at a temperature of zero F. The heat entering the coils comes from the surrounding air or brine at a somewhat higher temperature, say 10 or 20 F. After the ammonia absorbs heat it vaporizes (boils) at zero F and as a gas it is compressed in a machine with a rising temperature until a temperature is secured such that the rejection of heat along the process *ba* is possible.

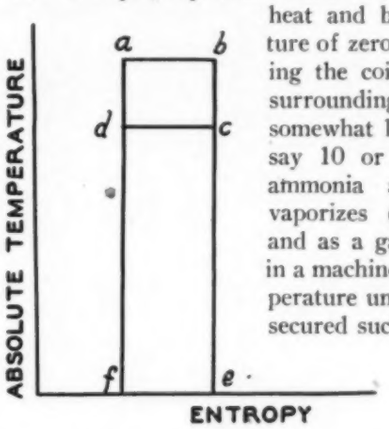


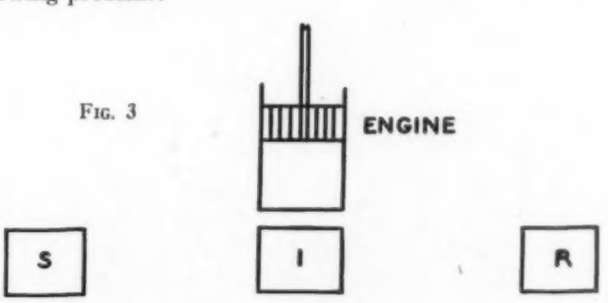
FIG. 2

For example if the cooling water used in a refrigerating plant is of such a temperature as will permit the liquefaction of the ammonia at 86 F then the pressure in the condenser against which the gas must be compressed will be about 155 lb. per sq. in. gage. Heat is actually absorbed at the lower and rejected from the working medium at the higher temperature. The action is similar to a water pump which takes water at a certain level and delivers it at a higher level, and a certain amount of work is supplied to the pump in order to make the cycle possible.

Problem Shows Refrigeration Process

The process of refrigeration can be shown by the following problem:

FIG. 3



* Associate Professor of Refrigeration, University of Illinois, Urbana, Ill.

A reversed Carnot engine is used for heating a building. The outside temperature is —10 F and the building is to be held at a temperature of 70 F. What is the heat absorbed from the outside atmosphere if 200,000 Btu per hour are required for heating, and what horsepower is required to operate the machine?

The efficiency is as before $E = \frac{T_1 - T_2}{T_1} = \frac{530 - 450}{530} = 0.1509$

as no machine can have a greater efficiency than a direct acting Carnot engine. The heat absorbed from the cold body is

$$E = \frac{Q_1 - Q_2}{Q_1} = \frac{200{,}000 - Q_2}{200{,}000} = 0.1509$$

$Q_2 = 169{,}810$ Btu per hour

As $AW = Q_1 - Q_2$ then $AW = 30{,}188$ Btu

$= 11.86$ hp. as one hp. $= 2546$ Btu per hour.

In the preceding problem the refrigerating cycle can be understood nicely. Work equivalent to 30,188 Btu per hour was performed on the working medium and 200,000 Btu of heat was obtained, giving a ratio of $\frac{200{,}000}{30{,}188} = 6.63$.

That this is not visionary can be seen from the usual refrigerating practice which allows 1 hp. of useful work (42.44 Btu per minute) per ton of refrigeration (200 Btu per minute) and the heat rejected to the condenser would be approximately 242 Btu per minute in the actual cycle. It would seem, therefore, that the use of the refrigerating cycle for the purpose of heating a building is possible.

Objections to Plan

However, with the methods under consideration, there are reasons why the scheme may not be utilized. A large plant representing a heavy first cost will be needed, the operation of which could be made automatic but would require some care from the operating engineer, thereby adding to the cost of operation. As the temperature in the condenser of the refrigerating cycle must be kept as low as possible, the maximum heating temperature of the medium for the building will be low. If the warm water system of heating is used, the radiation would need to be much greater than in the case of the present practice.

pH Method of Determining Acidity and Alkalinity

Editor's Note.—Published below are questions received from several engineers in charge of refrigeration systems. The answers of an authority on the subject appear with each question.

pH Values

QUESTION: Explain what is meant by *pH* values.

Answer: The *pH* system (potential hydrogen) is a rather complicated but valuable means of expressing the relative acidity or alkalinity of a given solution. It is based upon a mathematical expression of the concentration of H^+ions and OH^-ions in solution. The *pH* scale is a logarithmic expression of the degree of electrical dissociation at which the neutral point, or the point at which the hydrogen and hydroxyl ions are in a state of equilibrium, and the solution therefore neutral, is taken to be 7 (*pH* 7). As the *pH* number falls from 7.0 to 0 the solution is indicated to be more acid, and as the *pH* numbers rise from 7.0 to 14.0 a greater degree of alkalinity is expressed.

How pH Values Are Determined

Question: How can these *pH* values be determined?

Answer: Several forms of electrical apparatus, such as the hydrogen electrode and the more recently introduced glass electrode machines, are available for determining in an accurate manner the hydrogen ion concentration or *pH* value of a solution. Where absolute accuracy is not demanded, however, more rapid and less expensive methods may be used with satisfactory results.

These are based upon colorimetric determinations by the use of sensitive colored solutions which change color with slight changes in acidity or alkalinity. Different solutions have specific ranges of *pH* values over which they operate. For instance a given indicator may be yellow at one end of its range and red at the other end. The intermediate shades between these extremes are likewise representative of comparative changes in *pH* value. Phenol red, for example, is yellow in an acid solution of *pH* 6.8 passing through deep yellow and orange as the solution is made less acid and more alkaline until it becomes deep red when the solution reaches the alkaline *pH* value of 8.4. Color charts for obtaining the *pH* values of the intermediate shades are available with the indicators from any chemical supply house.

Precautions When Using Sodium Dichromate

Question: What precautions should be followed in using sodium dichromate in brine solutions?

Answer: The chief objections to the use of sodium dichromate are: (1) It is irritating to the skin of workmen who come in contact with the brine, causing an itching, and sometimes even poisoning in cases of severe exposure. Practically all of this trouble may be avoided as there is little reason for workmen to handle the brine solution. If the hands become wet with the brine they should be rinsed as soon as possible in clear water. The handling of calcium chloride brine is unpleasant at best and may cause considerable irritation whether it contains dichromate or not. (2) When dichromate is used in the condenser water that passes through cooling towers where the wind is likely to drive some of the spray upon adjoining property, damage to painted surfaces, stains upon masonry and damage to vegetation are likely to result.

For these reasons only the necessary amount of dichromate to prevent corrosion should be used in brine or condenser systems. If the minimum amounts are used, the corrosion committee of the A.S.R.E. reports that the dangers from the use of dichromate are very slight where reasonable and ordinary precautions are taken to prevent the solution from coming in contact with the skin of workmen.

How to Figure Amount of Water Used by Hydraulic Presses

By F. G. Schranz* and W. L. DeLaney*

The method of determining water quantities for hydraulic pressess is explained in this article. In a future paper, the way this water is supplied will be shown. The quantity, time, and pressure system determine the size and type of the piping to the press and the control equipment.

THE application of hydraulic presses to different problems introduces other considerations beside that of simply applying power. From the beginning of an operation to its conclusion is usually termed a cycle. The subsequent cycles are a repetition of the first.

Let us consider the problem of upsetting a piece of steel as concerns the operation of a simple press, having a ram which moves upward at the start or beginning of the cycle. The press ram will move upward through a partial stroke until the two ends of the steel billet are in contact with the platen or dies faces. The ram will continue to move upward exerting its full pressure and doing useful work in upsetting the steel the desired amount. At the end of the useful or working stroke means must be provided to return the ram to its initial position which completes its cycle. The distance the ram moves from its initial position until it begins to do useful work is commonly called its idle stroke; the remainder is the useful or working stroke.

The cycle outlined above for a single cylinder consists of a working stroke and a return stroke. This is the fundamental cycle of any cylinder. Hydraulic pressure is always required for the working stroke but the return stroke may be accomplished by gravity, the weight of the ram and other moving parts being sufficient to cause the water to flow out of the cylinder when connected to atmospheric pressure. This system has its practical limitations where speed is essential and is obviously unsuited to cylinders having rams which move in a horizontal position or in a vertical position where the working stroke is downward. (The press cylinder is above the work in this case.)

Returning the Ram

There are several other systems employed to accomplish the return of the ram. First, suitable weights are provided which produce the desired exhaust pressure in the cylinder when the working pressure is cut off. Second, springs which are compressed by the cylinder as it moves forward, will return the ram to its initial position. This type of return is only suited to rams with short strokes. Third, the piston may be made of the double acting type (trunk type) which permits pressure to be applied to alternate sides of the ram, giving a reciprocating motion. Fourth, the main ram may be arranged with one or more pull-back or push-back cylinders. These are usually small, single acting high pressure cylinders which transmit their movement to the main ram through a cross-head or other suitable means.

Examples

To cite a few examples of the type of presses using gravity return may be mentioned the following: presses for bakelite moulding, curing rubber heels and soles, belting and mat presses, linoleum presses, hard oil presses, battery jar, hose, crimping presses, wallboard, etc.

Presses arranged with ram return by counter weights: wheel presses, horizontal forcing presses and forming presses.

Presses arranged with ram return by means of double acting cylinders: drawing presses, pull benches, horizontal bull dozers, etc. (especially well adapted for long strokes).

Presses arranged with ram return by means of independent high pressure pull-back or push-back cylinders: forging presses, flanging presses, molding presses, pulp presses, etc.

Auxiliary Rams

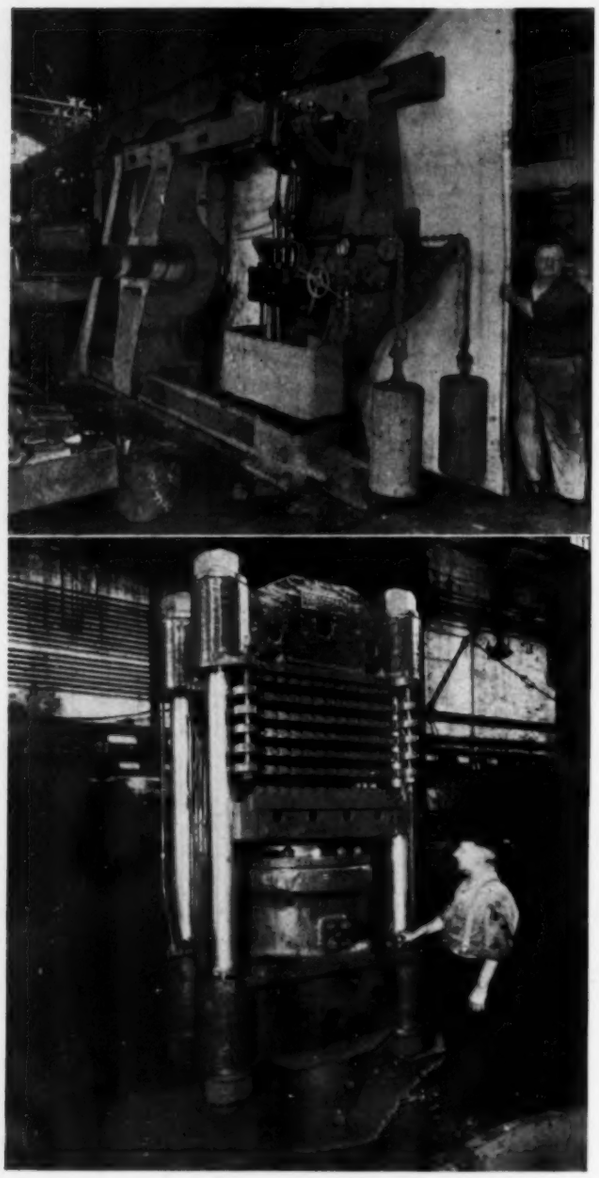
A press may have in addition to the main ram, a number of other auxiliary rams all of which have a function to perform in a process or cycle and which are operated independently of the main ram and in proper sequence. These rams are variously termed; clamping, jack, overhead, stripping, knock out, etc., are the ones commonly used. The nomenclature depends on the type of press to which they are applied, but their function is generally supplementary and often essential to the main function of the press. Clamping rams are used on flanging presses and drawing presses to clamp sheet metal to prevent wrinkling during drawing or cupping operations. Auxiliary rams may be used on the press for centering a plate before flanging, to punch manholes after flanging and to eject the drawn or flanged piece from the die. Another example of a press having multiplicity of action is one used for making heads for kitchen range boilers (hot water boilers). The plate is sheared to size, flanged, dished and the spud hole punched in one cycle (spud is the fitting into

* Southwark Foundry and Machine Co., Philadelphia.

which the pipe connection is threaded). Auxiliary cylinders are used on curb (rendering) presses for stripping the cake from the curb (basket) after the pressing operation.

Two-Pressure System

Above it is mentioned that presses often move through an idle stroke before beginning their actual working stroke. In certain cycles such as curing rubber soles or heels, the idle stroke is essential to facilitate handling the forming or curing molds into and out of the press, consequently a press is often operated at a pressure below that for which it is designed in order to conserve power. The system is commonly referred to as a two pressure system or high and low pressure system. Let us determine from a concrete example just how this affects the operation of the press.



Below—Multiple Opening Steam Platen Press for Curing Rubber Soles, Heels, Mats, Etc. Above—600-Ton Capacity Wheel Press with Ram Return by Pull-Back Weights

Let us assume a battery of ten presses at work on curing rubber soles. A press of this character may have a 22-in. ram working at 2,000 lb. per sq. in. with a capacity of 380 tons[1]; the area of the ram is also 380 square inches and will require $\frac{380}{231}$ gallons of water per inch of stroke = 1.64 gallons.

These presses also frequently have four openings (so that four molds may be inserted at once), four inches for each opening and 16 inch stroke of ram. If the molds are 2 inches thick when closed it is safe to assume they are 2½ inches before closing so that there is an idle stroke of $4 \times (4 - 2\frac{1}{2})$ or 6 inches and a power stroke of $4 \times (2\frac{1}{2} - 2)$ or 2 inches for each press.

If the ten presses were to operate simultaneously there would be a total of 60 inches of idle stroke and 20 inches of working stroke. When all molds are in, the total fluid requirements for 10 presses is 80 in. × 1.64 gallon per inch = 132 gallons. As the usual cycle is about 12 minutes, the average requirement is $\frac{132}{12} =$ 11.0 gallon per minute of which one-quarter is required for the power stroke or 2.75 gallons per minute and three-quarters for the idle stroke or 8.25 gallons per minute. If the whole 11.0 gallons were required at 2,000 lb. W. P. the theoretical power required is 11.0 × 1.167 or 12.83 hp., whereas if one-quarter is supplied at 2,000 and three-quarters at 250 lb. (an average W. P. for low pressure systems) the pressure would be (2.75 × 1.167) + (8.25 × 0.146) or only 3.33 hp.

Allowance for Leakage

These figures are only theoretical and for actual quantities allowance must be made for waste, leakages, and efficiency so as to insure ample supply at all times. The actual horsepower consumed is therefore higher than that stated above.

It is readily therefore seen that by operating at two different pressures often a saving can be effected which is a worth while factor in any plant.

If the cycle of the press is studied thoroughly as to time, ram diameters, length of strokes, etc., the quantity of water for any given set of conditions may readily be determined with the aid of the table[1] already published.

[1] See table, page 777, September, 1930, issue.

Lining Duct Reduces Noise

Experience with the reduction of noise from ventilating systems has indicated that noise from fans can usually be reduced from 10 to 15 decibels by lining the duct with sound absorbing material for a certain distance from the outlet of the duct, the distance depending upon circumstances. For a duct of normal size, the lining should be extended a distance of about 20 feet from the opening.

"Open for Discussion"

Exhausting Air from Apartment House Kitchens—Ventilator Noise in "Talkie" Theaters

Exhausts from Kitchen

A RECENT article[1] on handling kitchen exhausts in apartment houses was read with a great deal of interest inasmuch as the writer recently had occasion to design similar exhausts, one in an apartment house and the other in an apartment hotel, these buildings being 22 and 20 stories high, respectively.

It always has been the writer's opinion that exhaust systems cannot be designed along quite duplicate lines with supply systems, as he has found that when so treated it is very easy to upset their action, securing in some cases no action at all or a reverse action.

Odors from Kitchens to Bathrooms

One case occurred in an 8-story building located on Fifth Avenue in New York, where an exhaust fan in a pent-house on the roof was used to ventilate various bathrooms as well as the main kitchen in the basement. The kitchen exhaust duct was run entirely separate to

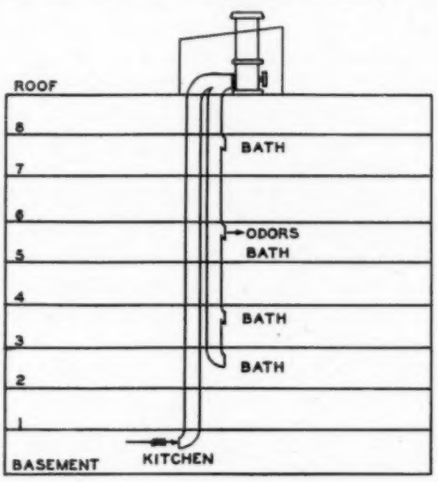


FIG. 1

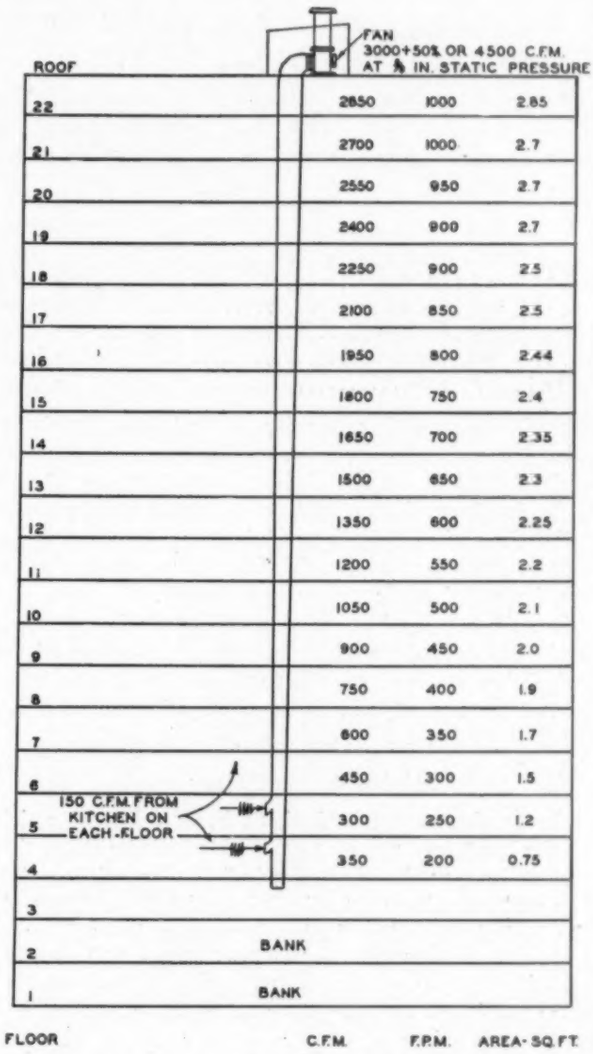
the fan in the pent-house on the roof and the bathroom exhausts were connected together into a trunk line which was also carried separately to the inlet of the same fan. This is illustrated by Fig. 1.

In spite of this separation, when onions were cooked in the basement the odor was very noticeable in the fifth floor bathroom unless the exhaust fan was operating. Of course when the fan was in operation no trouble was experienced; the difficulty lay in the fact that it was not desired to run the exhaust fan all the time.

Fan Capacity Enlarged

The scheme used for venting kitchens in the two apartment houses mentioned consisted of putting in a

[1] *Handling Kitchen Exhaust in an Apartment House*, by Samuel R. Lewis. HEATING, PIPING AND AIR CONDITIONING, p. 929, November, 1930.



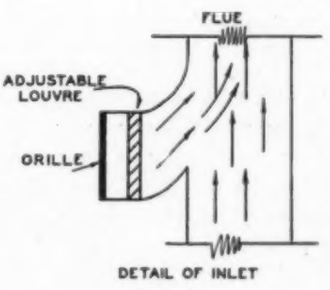


FIG. 2

vertical flue and exhaust registers (which favored the lower floors to compensate for the greater distance from the fan) and the use of a fan with considerable excess static and volume capacity over that theoretically required. Fig. 2 illustrates the typical features of these systems the quantity of air, the duct size, etc., shown being for the apartment house where the exhaust amounted to 150 c.f.m. per kitchen or about 10 air

changes per hour. In the apartment hotel 200 c.f.m. per kitchen was used with corresponding increases in flue and register sizes as these kitchens were somewhat larger.

Referring to Fig. 2, the lower rooms are favored by giving a proportionately larger size of flue at the bottom where the velocity starts off in the flue at 200 ft. per min. and gradually increases until it reaches 1,000 f.p.m. at the top. This does much to reduce the friction in the longer flue going down to the farther registers.

Register Sizes

The inlet grilles were provided with individual louvers to control the air flow as shown in the detail, Fig. 2, and the register sizes were graduated to favor the lower floors as follows:

3rd, 4th and 5th floors	12 x 18 in.
6th, 7th and 8th floors	12 x 16 in.
9th, 10th and 11th floors	12 x 14 in.
12th, 13th and 14th floors	12 x 12 in.
15th, 16th and 17th floors	12 x 10 in
18th, 19th and 20th floors	8 x 10 in.
21st and 22nd floors	8 x 8 in.

It will be seen that velocity through these registers varies from about 100 f.p.m. on the lowest ones up to nearly 350 f.p.m. on the highest ones. On top of this the fan has been given a capacity of 50 per cent in excess of the theoretical quantity of air to be handled. The static pressure has been made about 50 per cent more than the actual static pressure necessary.

Now the result of all this is that there will be a constantly maintained negative pressure at all points of the vertical flue and dead registers and reverse flow registers will not result except in times of high winds, in which case it is doubtful if much ventilation is needed.

Higher Static Pressure

The trouble complained about in Mr. Lewis' article (In the last paragraph on page 930) where he states that exhaust fans on the roof of a building experience difficulty and sometimes actually fail to lift the exhaust air out of a building when the heating system is not in service may be remedied by using fans with a higher static pressure. In other words, the exhaust fans must be capable not only of handling the volume air required at the static developing from duct friction, etc., but also must be able to handle the unbalanced candition caused by temperature. This additional amount of static pressure required will depend on the maximum temperature difference and the height.

Effect of Temperature Difference

If a maximum temperature difference which the building will be below the outside air is assumed at 20 F (and this seldom will be exceeded) with the building at 70 F and the outside temperature at 90 F the difference in weight per cubic foot would be

For dry air—

Weight at 70 F	0.07310 lb.
Weight at 90 F	0.06881 lb.
Difference in weight	0.00429 lb.

For saturated air—

Weight at 70 F	0.07425 lb.
Weight at 90 F	0.07094 lb.
Difference in weight	0.00331 lb.

and as water weighs 0.43 lb. per sq. in. per foot of height, an inch of water equals

$$0.43/12 = 0.0358 \text{ lb. per sq. in.}$$

Now the difference in weight between two columns of air 12 in. × 12 in. × 100 ft. high would be

$$0.00429 \text{ lb.} \times 100 = 0.429 \text{ lb. for dry air.}$$
$$0.00331 \text{ lb.} \times 100 = 0.331 \text{ lb. for saturated air.}$$

Ordinary air at about 50 per cent relative humidity would make the difference in weight practically an average of these two figures or

$$(0.429 + 0.331) \div 2 = 0.38 \text{ lb. per 100 ft.}$$

or

$$0.38 \div 144 = 0.00263 \text{ lb. per sq. in.}$$
$$0.00263 \div 0.0358 = 0.073 \text{ in of water.}$$

This would seem to indicate that if 1/10 in. is added to the ordinary static pressure for every 100 ft. of vertical height the fan would have no difficulty in removing the air even when the temperature in the building is 20 F less than the outside temperature.

Talking Pictures Stress Theater Ventilator Noise Problem

By Wallace Waterfall*

I WAS particularly interested in the experiment recorded in the article[1] on sound control in which the acoustical effects of a stream of warm air passing from the front to the rear of the auditorium were observed. Instances have been encountered where streams of warm air have caused acoustical difficulties, but I know of no instance where the flow of air in an auditorium has been satisfactorily utilized to improve acoustical conditions. As a rule, the air flow itself has very little effect on acoustics.

The ventilation system becomes of importance to the acoustical engineer because of the noise which it creates. This noise may come to the auditorium all the way from the fan, since the ducts usually are efficient as speaking tubes in transmitting sound. Sometimes the noise originates in the duct itself, due to the vibration of the metal. Noise from ventilating equipment is objectionable, because it masks speech sounds.

Newer Talking Pictures Make Problem More Important

Ventilation system noises become a problem of particular concern in theaters. With the silent pictures the ventilation noise was of little importance, because it was easily covered up by the organ or orchestra. With the earlier talking pictures, the "scratch" noise in the picture itself was great enough so that it usually covered up any ventilator noise. With the newer talking picture equipment, this "scratch" noise is being greatly reduced and consequently ventilator noises are becoming a more serious problem. If full advantage is to be taken of the new pictures, all noise in theaters due to the ventilating equipment and the audience must be greatly reduced.

*Acoustical engineer, The Celotex Company, Chicago.

[1] *Control of Sound in Buildings*, by F. R. Watson, Heating, Piping and Air Conditioning, December, 1930, p. 992.

Heating·Piping
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FEBRUARY 1931

Material in this Section prepared by Publication Committee: G. L. Larson, *Chairman;* H. H. Angus, and W. A. Rowe : A. V. Hutchinson, Manager of Publications

Table of Contents

Heat Emission from the Surfaces of Cast Iron and Copper Cylinders Heated with Low Pressure Steam, by A. C. Willard and A. P. Kratz.....141
Smoke and Dust Abatement, by Melvin D. Engle.....146
Air Conditioning in the Bakery, by W. L. Fleisher.....158
Heating Effect of Radiators, by R. V. Frost.....168
Utilization of Hot Springs for Heating in Iceland, by Ben Gröndal.....174
Program—37th Annual Meeting 179
Of Interest to Members.....180
Candidates for Membership.....181
Candidates Elected 182

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Heat Emission From the Surfaces of Cast Iron and Copper Cylinders Heated With Low Pressure Steam

By A. C. Willard[1] and A. P. Kratz[2] (*MEMBERS*), Urbana, Illinois

This paper attempts to explain why a cast-iron cylinder with walls 0.25 in. thick will transmit over 50 per cent more heat than a copper cylinder of exactly the same size with walls 0.01264 in. thick, when there is low pressure steam on the inside of the cylinders and air on the outside of the cylinders. Note that the cast-iron cylinder wall is almost 20 times as thick as the copper cylinder wall, and that copper has a conductivity approximately 8 times that of cast-iron per inch of thickness. Although the copper wall is $8 \times 20 = 160$ *times better than the cast-iron wall as a heat conductor, the overall heat transfer of the cast-iron cylinder is greater than that of the copper cylinder because of the greater surface emission of the cast iron.*

THERE appears to be more or less confusion[3] in the minds of heating engineers and others concerning the transmission of heat through, and the emission of heat from metal surfaces *exposed to air on one side and steam on the other.* This paper presents the results of some recent simple tests on cast-iron and copper cylinders as an illustration of certain well-known laws of heat transmission and emission under temperature conditions comparable with those which exist in heating buildings.

The authors make no claim for originality or novelty in either the scientific facts or the following discussion based on these facts. Acknowledgment is due E. L. Broderick, Research Assistant in Mechanical Engineering, who conducted at the University of Illinois the recent tests referred to in the paper.

General Statement

It is generally *assumed* that a thin layer of a given material will transmit more heat from the hot side, or surface, to the cool side, or surface, than a thicker layer of the same material, provided the hot surfaces are at the same temperature in both cases, and the cool surfaces are exposed to the same medium simultaneously.

It is also generally *assumed* that of two different materials of the same thickness, the material having the higher coefficient of conductivity will transmit more heat from the hot side, or surface, to the cool side, or surface, than the other material with a lower coefficient of conductivity, provided the hot surfaces are at the same temperature in both cases, and the cool surfaces are exposed to the same medium simultaneously.

There is a "joker" missing in both of the preceding assumptions, in that two important details or conditions have been omitted. These two details, which are commonly overlooked, are the type or character of the cool side or surface, and the nature or kind of medium on the cool side of the materials. Failure to keep these details in mind when considering the heat transmission of *metals* exposed to *steam* on the hot surface and *air* on the cool surface is the cause of the "confusion" referred to in the opening sentence of the paper.

So important are these details or conditions that, contrary to the generally *assumed* conceptions of heat transmission just presented, it may be readily demonstrated that a cast-iron cylinder 0.25 in. thick, painted a flat gray, will transmit 2.43 Btu per square foot per degree Fahrenheit per hour as compared with 1.41 Btu per square foot per degree Fahrenheit per hour for a clean copper cylinder of No. 28 gage metal (0.01264 in. thick), when both are supplied with steam at about 1 lb gage pressure, and the outer surfaces are exposed to air at about 75 F. Note that the walls of the cast-iron cylinder are almost 20 *times as thick* as the walls of the copper cylinder. Moreover, these apparently contradictory results exist in spite of the fact that the conductivity of copper is about 2,730 Btu per square foot per inch per hour per degree Fahrenheit, as compared with 325 Btu for cast iron. Note, therefore, that the conductivity of the copper cylinder walls is about 8 *times as great* as the conductivity of the cast-iron cylinder walls *per inch of thickness.*

Test Plant and Procedure

The simple tests already referred to were made with the same type of plant (Fig. 1) as that used in an earlier study[4] of the heat emission from various surfaces, using cylinders 10 in. in diameter and 20 in. in length, of copper, cast-iron and sheet iron. The plant as actually used in these recent tests is shown in Fig. 2 and has been in service for several years.

Saturated steam was supplied to the cylinders at a pressure of about 1½ in. mercury or 215 F, and the air surrounding the cylinders was approximately 75 F. Since all tests were run simultaneously in still air, slight

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[3] Such statements as "radiators today are built *with thinner walls,* which allow a ready escape of the heat," taken from a paper which has just appeared in print, are common examples of this "confusion."

Presented at the 37th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Pittsburgh, Pa., January, 1931.

[4] Emissivity of Heat from Various Surfaces, by V. S. Day (Engineering Experiment Station Bulletin No. 117, University of Illinois).

variations in conditions were reflected equally in the performance of all cylinders.

A thermocouple of copper and constantan wire, No. 34 B. and S. gage, was attached flush with the outer surface of the cast-iron cylinder and located on a horizontal diameter, where the metal was 7/32 or 0.219 in. thick. The average thickness of the cylinder was ¼ or 0.25 in.

The test procedure was very simple. All cylinders and seals were thoroughly blown out by raising the steam pressure just a trifle. The pressure was then reduced to the operating condition of 1½ in. mercury and the running seals allowed to fill up to normal running position. See Fig. 1. The thermometer at the outlet of each cylinder was read just before the test started, and the weight on each scale was recorded. Since there was no measurable pressure drop between the steam supply drum and the cylinders, the outlet thermometers always indicated the steam temperature at the start of the test, and continued to do so throughout the test *unless* air accumulated above the *water column* in the running seals. Frequent readings of these thermometers were made during the period of each test, and all tests terminated at the first sign of any drop in temperature at any outlet, at which time the weight on each scale was again recorded. In most cases, this did not occur for periods of from five to ten hours. In all cases, tests were repeated and checked. The condensate discharged from each running seal (Fig. 1) was taken through a short piece of rubber tube submerged in the bucket receiver on each scale.

Test Results

From the latent heat of the saturated steam condensed, corrected for 2.5 ft. of exposed ¼ in. diameter pipe, it was a simple matter to compute the heat given off from the surface of the cylinders by means of the following formula:

$$K = \frac{rW}{A\,(t_s - t_a)}$$

where

K = Btu per square foot per hour per one degree Fahrenheit
r = latent heat of one pound of the steam, in Btu.
W = corrected weight of condensate per hour, in pounds
t_s = temperature of the steam, in degrees Fahrenheit
t_a = temperature of the surrounding air, in degrees Fahrenheit
A = area of the drum exposed to the air, in square feet

It should be noted that tests of the quality of the steam, with drain or bleeder at bottom of steam drum open, invariably showed better than 98 per cent and often better than 99 per cent. The amount of the ¼ in. pipe exposure correction was ascertained from calibration tests with all the ¼ in. pipe heavily insulated with hair felt.

The test results are shown in Table 1. Two values

TABLE 1—RESULTS OF HEAT EMISSION TESTS WITH METAL CYLINDERS[a] CONTAINING STEAM AT ABOUT 215 F AND STANDING IN STILL AIR AT ABOUT 75 F

SPECIAL NOTE: In no case was the temperature of the outside surface of the metal as much as 0.5 deg. less than the steam temperature in the cylinder.

Item No.	Description of Metal Cylinders	Heat Transmission Coefficient-K in Btu. per sq. ft. per hr. per 1° F.	Relative Heat Transmission
1	Cast iron, 0.25", foundry finish	2.21	1.57
2	Cast iron, 0.25", painted a dull flat gray	2.43	1.72
3	Sheet iron, No. 28 gage (0.0156"), very rusty	2.37	1.68[b]
4	Sheet copper, No. 28 gage (0.0264"), slightly dull, but not corroded	1.58	1.12
5	Sheet copper, No. 28 gage (0.0264"), recleaned like new	1.39	0.99
6	Sheet copper, No. 28 gage (0.0264"), clean new surface	1.41	1.00[b]
7	Sheet copper, No. 28 gage (0.0264"), painted with blue-drab gray automobile enamel, 45% pig.–55% Varn	2.42	1.72[b]

[a] Each cylinder was 10 in. diameter x 20 in. long, having an outside surface area of about 5.5 sq ft.
[b] From previous work, University of Illinois.

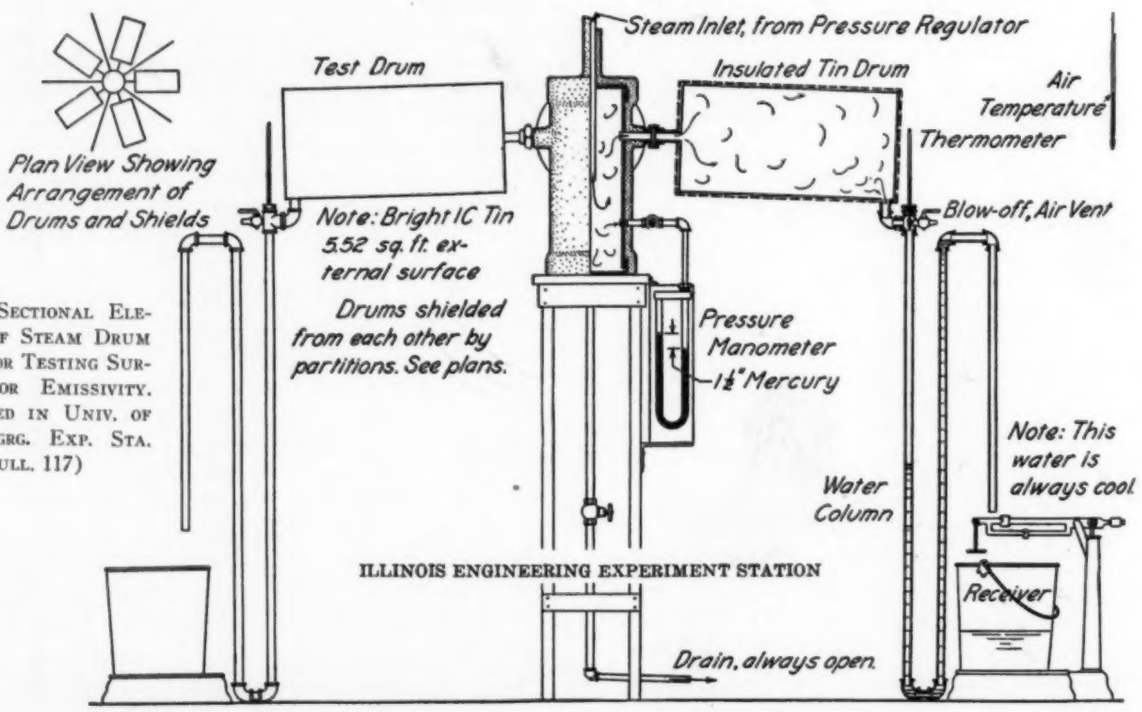
Steam Inlet, from Pressure Regulator
Test Drum
Insulated Tin Drum
Air Temperature Thermometer
Plan View Showing Arrangement of Drums and Shields
Note: Bright IC Tin 5.52 sq. ft. external surface
Blow-off, Air Vent
Drums shielded from each other by partitions. See plans.
Pressure Manometer
1½" Mercury
Note: This water is always cool
Water Column
ILLINOIS ENGINEERING EXPERIMENT STATION
Receiver
Drain, always open.

FIG. 1—SECTIONAL ELEVATION OF STEAM DRUM PLANT FOR TESTING SURFACES FOR EMISSIVITY. (AS USED IN UNIV. OF ILL. ENGRG. EXP. STA. BULL. 117)

from previous work (University of Illinois) are included for comparison.

Discussion of Results

It is most essential to keep certain temperatures in mind in any discussion of the results shown in Table 1. The steam temperature in the cylinders was 215 F, ± 1 deg. (F); the temperature of the inside surface of the cylinders against which the steam was condensing is not known, but it was almost identical with that of the steam; the temperature of the outside surface of the cylinders was well within 0.5 deg (F) of the steam temperature, probably very much less than 0.5 deg (F) in the case of the copper cylinders; and the temperature of the surrounding air and "visible" objects was approximately 75 F, ± 5 deg (F). Actual temperature measurements with the copper-constantan thermocouple at the air surface f the cast-irn cylinder ranged frm 214.70 F to 214.60 F for the plain foundry finish and flat gray painted furfaces respectively, when the steam temperature was 215 F.

Since the resistance to heat flow into or out of a surface, or through a material from face to face, varies almost directly with the temperature differences, it will be apparent that the resistance at the outside surface of all the cylinders is, comparatively speaking, simply enormous. The temperature drop from the outside surface *to the surrounding* "air" and "visible" objects is of the magnitude of $(215 - 75) = 140$ F, whereas the total temperature drop at the inner surface, and through the metal wall of the cylinders, is less, much less, than 0.5 deg (F). It will be further apparent that considerable changes in the thickness of the metal cylinder walls will have very little effect on the outer surface temperature and hence on the resistance (always nearly proportional in any given case to the temperature difference across the surface) at the air surface.

The "neck of the bottle" in all the cases shown in Table 1 is encountered as the heat attempts to pass from the outer metal surface of the cylinders to the surrounding "air" and "visible" objects. Just how this heat escapes from this surface depends on the well known laws of radiation, conduction and convection and is discussed in a subsequent section of the paper, but some reference must be made to the matter of radiation effects in discussing certain other aspects of the results in Table 1.

It has been shown that the metal thickness and conductivity are relatively unimportant when the cylinders are surrounded with air, but why should the thick, low-conductivity cast-iron cylinders lose *more heat* than the thin high-conductivity copper cylinders? The outer surfaces of all cylinders are at about the same temperature, but the *character of the surfaces* are quite different, and this condition has a material effect on the amount of heat given off from the surfaces by radiation. All bright, hard, mirror-like surfaces give off less radiant heat than dull, porous, non-mirror like surfaces *at the same temperature* and with the same surroundings. It has just been pointed out that all of these surfaces are within 0.5 deg (F) of the steam temperature, hence changes in *surface finish* may become very important, and it is found that, *regardless of the thickness or conductivity of the cylinders used in these tests,* the heat transmission (Table 1) varies with the surface finish,

FIG. 2—PLANT FOR HEAT TRANSMISSION TESTS, STEAM TO AIR, USING CYLINDERS OF DIFFERENT METALS AND SURFACE FINISHES

being a minimum ($K = 1.39$ and 1.41) for the new or recleaned copper cylinders, and a maximum ($K = 2.43$) for the dull flat gray painted cast-iron cylinder, while for a cast-iron cylinder with a natural foundry-finish $K = 2.21$. Even a slightly dull surface on a copper cylinder increased the heat transmission to $K = 1.58$. By merely painting the copper cylinder, its heat transmission may be still further increased to $K = 2.42$, obtained in earlier tests with this same plant. It is interesting to note that the painted copper cylinder transmits almost precisely the same amount of heat as the painted cast-iron cylinder. The K values are 2.42 and 2.43 for painted copper and painted cast iron respectively. Surface finish becomes a matter of prime importance whenever radiation plays an important part in the emission of heat from a metallic surface, as in these tests.

Finally, any heat which was not discharged or emitted from the cylinders by radiation must be removed by conduction and convection to the surrounding air and was doubtless more or less uniform in amount, since the surfaces of all the cylinders were at about the same temperature, and the cylinders were surrounded with air of uniform temperature having no initial motion. A detailed analysis of the problem in which a mathematical computation of proportional amounts of heat discharged or emitted from the cylinders by radiation, conduction and convection follows.

Analytical Study

A vast amount of experimental data have been collected by investigators working in the field of heat transfer by radiation, conduction, and convection, and involving plane, cylindrical, and spherical surfaces of various natures. These investigations have covered the range from wires only a few thousandths of an inch, to pipes several feet in diameter, and have included both natural and forced convection in various fluid media. More recently the attention of physicists has been directed to correlating this mass of data, making use of the laws of dimensional homogeneity, and the present theory has been perfected to such an extent that the heat emission from various surfaces by radiation and natural convection can be calculated with sufficient accuracy for all practical purposes, provided the shape can be evaluated in geometrical terms and the nature of the surface can

be definitely specified. Hence, no further tests seem necessary to establish fundamental principles and constants. Most of the uncertainties arise in the cases of random shapes and of materials having surfaces of variable or indefinite texture, such that they cannot be identified with any of the physical constants now available. Tests on these special cases may be necessary in order to establish performance data for individual pieces of apparatus, but the results will be applicable only to that particular apparatus under the conditions existing at the time of the test. The tests reported in this paper serve very well to illustrate the degree to which the general theory can be made to apply.

In the case of the cylinders under consideration, the heat from the steam is transferred through the steam film on the inside surface of the cylinder and through the metal walls by conduction. It is then lost from the outside surface of the cylinder by radiation and conduction through the air film on the outside. The latter heat is finally removed from the air film by natural convection. Since the heat transferred through the steam film and walls by conduction is equal to that lost from the surface by radiation and finally by convection, the problem may be completely solved by evaluating the radiation and convection.

The radiation may be calculated from the well known Stefan-Boltzman equation

$$H_r = 0.1723\, e \left[\left(\frac{T_1}{100} \right)^4 - \left(\frac{T_2}{100} \right)^4 \right] \qquad (1)$$

where

H_r = heat loss by radiation, Btu per square foot per hour

e = emissivity coefficient, decimal fraction of black body radiation.

T_1 = absolute temperature $(t_1 + 460)$ of the hot surface, degrees Fahrenheit.

T_2 = absolute temperature $(t_2 + 460)$ of the surrounding air and "visible" objects, degrees Fahrenheit.

Table 2 gives the values of e to be used in equation (2) for a number of materials in common use.

TABLE 2—EMISSION COEFFICIENT (e) FOR VARIOUS SURFACES AND SURFACE TEMPERATURES

SURFACE	e_{100}	e_{200}	e_{302}	SOURCE
Cast iron, oxidized	.....	0.940	.....	Hütte[a]
Rough steel plate	0.945	0.950	0.961	Heilman[b]
Asbestos paper	0.930	0.934	0.943	Heilman[b]
Flat black lacquer	0.960	0.980	.....	Heilman[b]
Black lacquer	0.800	0.950	.....	Heilman[b]
White lacquer	0.800	0.950	.....	Heilman[b]
Copper, slightly polished	.....	0.167	.....	Hütte[a]
Copper, calorized	.....	.....	0.180	International Critical Tables
Copper, oxidized	.....	.....	0.568	International Critical Tables

[a] Des Ingenieurs Taschenbuch, 22nd edition.

[b] Surface Heat Transmission, (Mechanical Engineering, May, 1929, Section 1.)

The convection may be calculated from Heilman's[5] modification of the Rice[6] equation.

$$H_c = C \left(\frac{1}{D} \right)^{0.2} \times \left(\frac{1}{T_a} \right)^{0.181} \times \Delta t^{1.266} \qquad (2)$$

where

H_c = heat loss by convection, Btu per square foot per hour.

C = a constant depending on configuration.

D = diameter, inches.

T_a = average of the *absolute* temperatures of the surface and the surrounding air, degrees Fahrenheit.

Δt = temperature difference between the surface and the surrounding air, degrees Fahrenheit.

Table 3 gives the values of the constants (C) to be used in equation (2) for various shapes of surfaces.

TABLE 3—CONFIGURATION CONSTANTS (C)

Horizontal cylinders	1.016
Long vertical cylinders	1.235
Vertical plates	1.394
Horizontal plates facing upward	1.790
Horizontal plates facing downward	0.896
Spheres	1.820

It may be noted that both equations (1) and (2) are based on the actual surface temperature. If only the temperatures of the steam in the cylinder and surrounding air are known, and the surface temperature and rate of heat transmission are unknown, it will be necessary to assume a reasonable rate of heat transmission and make a trial calculation for the temperature, and from this calculate the transmission. These results may then be used in a second calculation to obtain a closer approximation. Usually the second is sufficient. In the case of the cast-iron cylinder under consideration the tests had shown the value of K, or the heat emitted per square foot of surface per degree difference in temperature per hour, to be approximately 2.4 Btu and one trial calculation proved to be enough.

McAdams,[7] Sherwood, and Turner found the resistance of the steam film on the steam side to be $\frac{1}{2{,}000}$. The thickness of the wall of the cast-iron cylinder used for the tests was 0.219 in. at the point where the surface thermocouple was located. The conductivity of cast iron is given[8] as 325 Btu per square foot per degree difference in temperature per inch per hour. Hence, the resistance of the wall was $\frac{0.219}{325}$, and the total resistance of wall and film $= \frac{1}{2{,}000} + \frac{0.219}{325} = 0.001175$. The combined conductance would, therefore, be $\frac{1}{0.001175} = 850$.

Since the temperature of the steam in the cylinder was 215 F, the air temperature 75 F, and the coefficient of heat transmission was approximately 2.4, the probable surface temperature can be calculated from the equation

$$2.4\ (215 - 75) = 850\ (215 - t)$$

$$\therefore t = 214.6 \text{ F.}$$

This calculation indicates that the drop in temperature through the film and wall did not exceed 0.4 deg (F), and the surface temperature could be taken as 215 F with sufficient accuracy for all practical purposes.

The average of the surface temperatures, as observed by means of the surface thermocouple, was 214.70 F for the cast-iron cylinder with the foundry finish and

[5] Surface Heat Transmission, R. H. Heilman (Mechanical Engineering, May 1929, Section 1).

[6] Chester W. Rice (A. I. E. E. Transactions, Vol. 43, 1924).

[7] Heat Transmission in Surface Condensers, by W. H. McAdams, T. K. Sherwood and R. L. Turner (A. S. M. E. Transactions, Vol. 48, 1926, p. 1246).

[8] International Critical Tables, Vol. 5, p. 221.

TABLE 4—CALCULATED HEAT LOSS BY RADIATION AND CONVECTION

Cyl. No.	Kind and thickness of metal and condition of surface	Heat loss, Btu per sq ft per hour			K		
		Convection	Radiation	Total	By Calculation	By Test	Per cent Diff.
1	Cast iron, 0.25 in., foundry finish	107	205	312	2.23	2.21	1.0
2	Cast iron, 0.25 in., painted dull flat gray	107	214	321	2.30	2.43	6.0
3	Sheet iron, No. 28 gage, very rusty	107	205	312	2.23	2.37	6.0
4	Sheet copper, No. 28 gage, slightly dull, not corroded	107	124	231	1.65	1.58	4.0
5	Sheet copper, No. 28 gage, recleaned like new	107	37	144	1.03	1.39	35.0
6	Sheet copper, No. 28 gage, clean new surface	107	37	144	1.03	1.41	37.0
7	Sheet copper, No. 28 gage, painted with blue-drab gray auto-engine enamel, 45 per cent pigment, 55 per cent varnish	107	214	321	2.30	2.42	5.0

214.61 for the same cylinder painted flat gray. This is in remarkably close agreement with the calculated surface temperature of 214.6 F. Since the drop in temperature through the steam film and 0.219 in. wall of the cast-iron cylinder was less than 0.4 deg (F), it may be reasonably assumed that the drop in the case of the thin walled copper cylinder was virtually nothing.

Since all of the cylinders had the same outside dimensions, the heat loss by convection would be the same for all. This loss by convection may be calculated from equation (2). On cylinders of this size no appreciable error will be made by regarding the ends also as cylindrical surface, in which case the value 1.016 may be used for C.

$$H_c = 1.016 \left(\frac{1}{10}\right)^{0.2} \times \left(\frac{1}{605}\right)^{0.181} \times (140)^{1.268}$$

$$= \frac{1.016 \times 530}{1.585 \times 3.19} = 107 \text{ Btu per square foot per hour.}$$

The heat loss by radiation may be calculated from equation (1). In the case of the cast-iron cylinder with foundry finish it is

$H_r = 0.1723 \times 0.94 \left[(6.75)^4 - (5.35)^4\right] = 205$ Btu per square foot per hour.

The total heat loss is, therefore, $107 + 205 = 312$ Btu per square foot per hour, and since the temperature difference from the surface to the air is 140 F,

$$K = \frac{312}{140} = 2.23 \text{ Btu per square foot per degree Fahrenheit per hour.}$$

This is in very close agreement with the value 2.21 determined by test for the same cylinder. The heat loss by radiation and convection, and values of K have been calculated in the same manner for other cylinders and are given in Table 4.

From Table 4 it may be observed that reasonably close agreement was obtained between the calculated and observed values of K in all except cylinders Nos. 5 and 6. In these two cases, the value $e = 0.167$ for slightly polished copper was used in the radiation equation (1). This value was probably obtained for a copper surface which had been machined and buffed. The surface of the rolled commercial sheet used in the test cylinder evidently did not correspond to this, but was oxidized to a certain extent. After the cylinder had been allowed to stand in the air for several months the surface was well oxidized, but not corroded. Hence, close agreement was obtained in the case of cylinder No. 4 for which the value of $e = 0.568$ for oxidized copper was used. The latter will probably be applicable for heat transfer apparatus that has been in use for any length of time. For new apparatus a value $e = 0.41$ seems to be indicated from the tests.

From Table 4 it is also evident that the variations in K, or the heat transmission from the cylinders, was brought about by variations in the radiation. The latter varied from 37 to 214 Btu per square foot per hour, or from 35 to 200 per cent of the heat loss by convection. Since radiation is purely a surface effect, and the drop in temperature through metal walls, even of considerable thickness, is negligible, it is also evident that the heat loss from metal cylinders with steam on one side and air on the other will be largely determined by the nature of the surface and not by the character or thickness of the metal forming the walls. If the nature of the surface can be identified with any of the known physical constants for radiation and the shape can be evaluated in geometrical terms, it is possible to predict the heat emission very closely from the theory available.

It is also of interest to note, both from Table 2 and Table 4, that since radiation plays a very important part in the heat transfer under the conditions discussed, the various paints will have practically the same effect irrespective of color, provided these paints consist of a pigment with an oil, varnish, or lacquer base.

Conclusions

1. The conductivity of a metal may bear little or no relation to the amount of heat emitted from a cylinder made of that metal when filled with saturated steam and surrounded with still air.

2. The actual metal thickness, within rather wide limits, has little or no relation to the amount of heat emitted from a metal cylinder filled with saturated steam and surrounded with still air.

3. The surface finish is an all important factor in the heat emission from metal cylinders filled with saturated steam and surrounded with still air.

4. The resistance to heat flow from the outer surface of a metal cylinder filled with saturated steam, when still air is the surrounding medium, is relatively enormous when measured in terms of the resistance of the metal wall itself, or the resistance at the inner (steam) surface of the cylinder.

5. The heat flow from the surface of a metal cylinder filled with saturated steam, when still air is the surrounding medium, may be calculated with a degree of accuracy sufficient *for all practical purposes,* provided the nature of the surface can be definitely specified and conforms with the radiation constants now available.

Smoke and Dust Abatement

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NON-MEMBER

THE CONCENTRATION of industrial activity around the large cities of the world has brought to the inhabitants of those densely populated areas new problems of many kinds. The problems of law and order, sanitation, water supply, transportation, and communication were some of the first to receive attention. After years of research and experimentation and the expenditure of vast sums of money, more or less satisfactory solutions have been found, but the ideal has not been achieved and probably will not be for some time.

Another problem resulting from the concentration of industry and habitation is that of air pollution. In 1661 strenuous objections were raised to the dust from sea-borne coal being unloaded in London, but according to the literature on the subject nothing was done to abate the nuisance. One writer referred to it as "the hellish cloud of sea-borne coal which maketh the city of London resemble the suburb of hell." During the period of almost three centuries since this blast against air pollution, the nuisance has increased many fold, but it has been only during the last decade that the problem has begun to receive the attention it deserves.

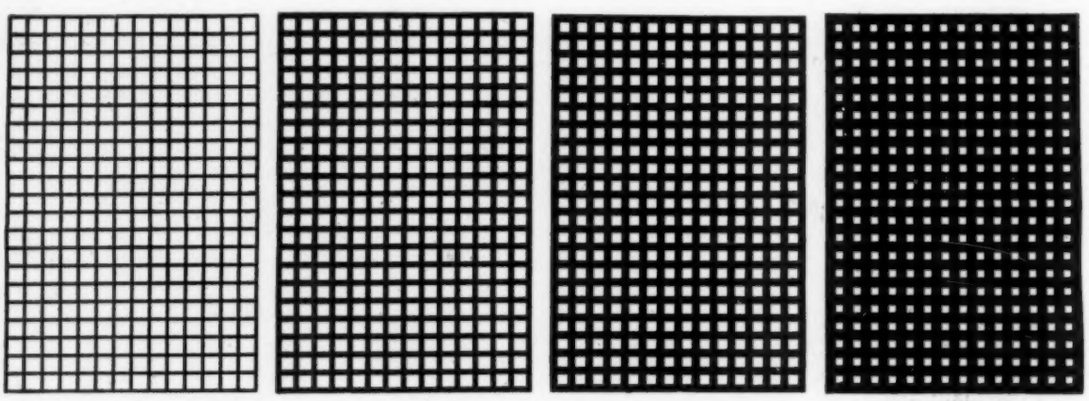

FIG. 1—RINGELMANN'S SCALE FOR GRADING THE DENSITY OF SMOKE. LEFT TO RIGHT: 1. EQUIVALENT TO 20 PER CENT BLACK; 2. EQUIVALENT TO 40 PER CENT BLACK; 3. EQUIVALENT TO 60 PER CENT BLACK; 4. EQUIVALENT TO 80 PER CENT BLACK

The main problem can be logically divided into three principal subdivisions; namely, smoke, dust, and noxious gases.

Smoke

The dictionary defines smoke as "visible vapor or volatile matter that rises from a burning substance," but for the purpose of this discussion smoke will be defined as the finely divided solid matter formed by the incomplete or arrested combustion of the volatile hydrocarbons in fuel.

Prof. W. E. Gibbs in his book "Smoke and Clouds" classifies smoke as those particles ranging in diameter from 1/1000 to 1/10 of a micron. A micron is 1/1000 of a millimeter. This gives an idea of the infinitely small size of smoke particles.

It is furthermore known that smoke particles will not settle in still air. Sometimes several smoke particles will stick together and fall to the earth, but as long as the particles remain separated, they will not settle. This means that the problem of catching them is almost hopeless in the light of present-day knowledge.

It has been found, however, that it is possible by the proper design and operation of the fuel burning equipment and furnaces to practically prevent the formation of smoke. It may be definitely stated, therefore, that the problem of smoke abatement can be solved by the selection of the proper fuel burning equipment and furnace design for the particular fuel to be burned, and by the proper operation of this equipment.

Where the equipment and furnaces are already installed, the problem of smoke prevention is not so simple. A change in the fuel burned or any one of a number of things can be done to improve conditions. The finding of the proper solution for a particular installation is quite often enough to tax the ingenuity of the cleverest engineer.

The first step taken toward air pollution abatement was the passing of the so-called *smoke laws*. Such laws were on the statute books for several years before any standard means were available for measuring

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smoke density. The well-known Ringelmann charts, shown by Fig. 1, were then devised and are the accepted measure of smoke density today.

The smoke laws have failed materially to abate the nuisance for two reasons: *First*, they were not based on a complete understanding of the problem; and *second*, because such nuisances cannot be abated by the passing of laws alone. They require extensive research and the expenditure of vast sums of money for experimentation and the development of the necessary equipment.

The experience of the city of Pittsburgh well illustrates the point. The Mellon Institute made a soot fall test for the city in 1914 and a smoke law was passed. In 1924 the same institution made a second soot fall test in exactly the same manner, and it was found that although the tarry matter in the soot collected was reduced from 10 tons to 3⅓ tons per square mile per year, the total solids had increased from 1,000 tons to 1,400 tons per square mile per year. The smoke nuisance had been abated, but the air pollution nuisance had increased 40 per cent.

Dust

For the purpose of this discussion, dust may be considered as any solid particles larger than the largest smoke particle, or any particle larger than 1/10 of a micron.

Dust particles varying in sizes from 1/10 to 10 microns in diameter settle in still air at a constant velocity depending upon their size, and particles larger than 10 microns settle in still air at a constantly increasing velocity.

It is obvious that the problem of separating dust from boiler flue gases becomes increasingly difficult as the size of the dust particles grows smaller. A relatively simple device will collect the large particles of coke or ash that are occasionally discharged with the flue gases, but the problem of collecting the finer particles of dust is extremely difficult. Unfortunately, by far the greater part of the dust in boiler flue gases is extremely fine.

The exact size of dust particles in the flue gas of coal-fired boilers varies greatly depending upon a number of factors, but for pulverized coal-fired boiler flue gas, in general, 90 to 95 per cent will pass through a 200-mesh sieve, and from 65 to 80 per cent will pass through a 325-mesh sieve. Particles that will just pass through a 325-mesh sieve are approximately 43 microns in diameter. No reliable data are available on the size of the dust in the flue gases from stoker-fired boilers, but it is known, in general, that by far the greater part of it will pass through a 200-mesh sieve.

The ideal, of course, is to catch all dust particles and at the present stage of development of the art of dust catching it might as well be admitted that it is not known how to accomplish the ideal. However, practically all of the coarse particles and a fair percentage of the smaller particles can be caught. As the art of dust catching progresses, and as the equipment is improved and new types of equipment are developed, it will be possible to catch a larger and larger percentage of the finer dust particles.

Fortunately, the larger dust particles constitute the greatest nuisance and as the size of the dust particle diminishes, the seriousness of the nuisance diminishes also. Some engineers will question the accuracy of this statement, but a careful study will prove its accuracy. In support, it is known that fly ash which will pass through a 300-mesh sieve but which will be retained on a 325-mesh sieve will carry approximately four miles when discharged from a chimney 200 ft. above the ground into a 10-mph wind. Particles of fly ash one-half this size will carry approximately 20 miles when discharged to the atmosphere at the same height above the ground in a wind of the same velocity. Consequently, for a given quantity of dust discharged to the atmosphere, the finer the dust, the smaller will be the deposit in tons per square mile per year, and the dust load per cubic foot of atmosphere. This statement is offered as a basis of discussion with the belief that such discussion will be helpful in the solution of the problem.

The measurement of the quantity of dust existing in the air is an extremely difficult one, and no two methods in use today will give the same answer. The impact dust counters, in which a measured quantity of air is drawn through an aperture and impinged against a microscope slide, give the highest dust counts of any methods in general use.

Doctor Free has conducted some very interesting dust counts in the city of New York, and he reports counts varying from 35,000 to 880,000 particles per cubic foot of air. These counts were taken from the seventeenth story of a building at 23rd Street and Fifth Avenue, New York City, and he estimates that the dust counts at the street level would be 50 to 100 per cent greater.

By measuring the size of the dust particles in the air, Doctor Free has estimated that there is an average of about one ounce of dust per 10,000,000 cu. ft. of air and that the air over the entire city of New York contains approximately four or five tons of dust. Particular attention is called to this figure, published by a recognized authority, to offset the statements that have been made by others that the air over the city of New York contains several thousand tons of dust.

Where does this dust come from? Doctor Free reports that his examination of the dust in the air above New York City shows that over 90 per cent of it is "clearly ordinary soot, that is, unburned carbon." Particles of rubber from automobile tires, asphalt, brick, rock, organic materials, and of leather, cotton fibers, hair, and other materials too numerous to mention contribute to the dust. The absence of ash particles in the air is particularly noteworthy, but it is not surprising in view of the large amount of carbon that must be discharged at low levels by the exhaust of automobiles, and the chimneys of residences, small apartment houses, office buildings, and small industrials, burning large quantities of coal in completely water-cooled furnaces and at very low furnace temperatures. Large furnaces operating at high temperatures and under competent supervision do not discharge as much carbon to the atmosphere as is generally supposed.

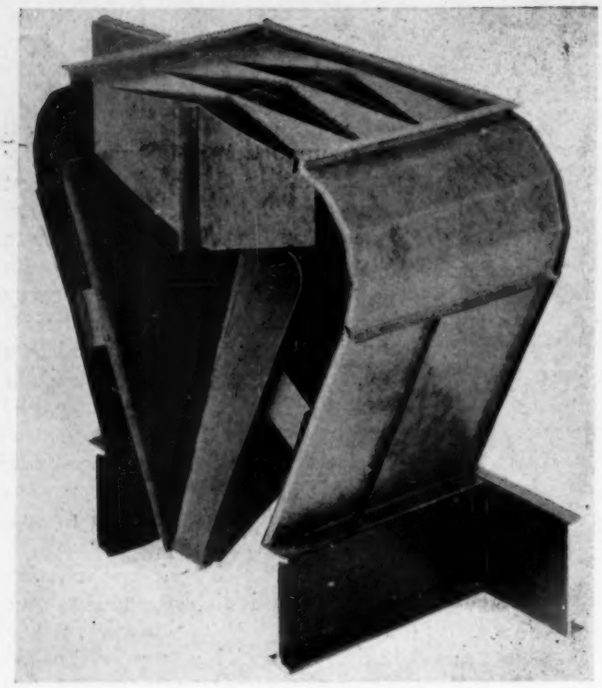


FIG. 2—DUST CATCHER

The first real start in the cleansing of the flue gases discharged from chimneys was made in those industries where the value of the dust reclaimed would pay for the necessary equipment for collecting. Metallurgical and cement plants have struggled with the problem for years.

The dust reclaimed from the flue gases of pulverized coal-fired boiler plants is valueless today. Those who have been willing to spend money to abate the nuisance of air pollution by these plants without a chance of a return on the money invested in the collecting equipment deserve special commendation for the public-spirited attitude which prompted them.

The companies operating large boiler plants are fully alive to the necessity for smoke and dust abatement. They have gone a long way toward the elimination of smoke, and they are demanding equipment for the catching of the dust in the boiler flue gases. These demands have resulted in the development of a large number of different types of dust catchers, and many more are in the process of development.

The dust catchers available may be divided into the following general classes:

1. Settling Chambers.
2. Dust Traps.
3. Centrifugal Separators.
4. Electrostatic Precipitators.
5. Gas Scrubbers.
6. Filters.

Settling Chambers

Probably the earliest attempts to catch dust in large quantities were made by the operators of blast furnaces. The gases were discharged into large settling chambers and the velocity of the gases reduced to a point where a considerable portion of the dust settled out by gravity. The bottoms of these chambers were provided with dump plates through which the collected dust was removed. These settling chambers were very effective for removing the large particles of suspended matter and went a long way toward reducing the air pollution nuisance due to the operation of blast furnaces. They were unable, however, to effectively remove the fine dust, and where large quantities of gas are to be handled these chambers become so large and expensive that they are not commercial. Furthermore, it is not practical to install such chambers on the suction side of induced draft fans operating at high suctions. They marked the earliest attempts to solve the problem of air pollution by dust, however, and played an important part in the development of the art of dust catching.

Dust Traps

It is not readily determined whether the so-called dust traps or the centrifugal dust catchers were the next step in the development, but probably the dust trap came next. Operators of settling chambers probably found that by varying the shape of the chambers and by the use of baffles higher efficiencies of collection could be obtained, and these experiments probably led to the development of the earliest forms of dust traps. Many different types are manufactured today, and the designs show plainly the ingenuity of those who have developed them. The results obtained in some cases are almost startling.

It would appear that dust traps should be able to operate equally well at any gas temperature. Recent experience has shown, however, that the temperature of the gas does have a marked effect upon the effi-

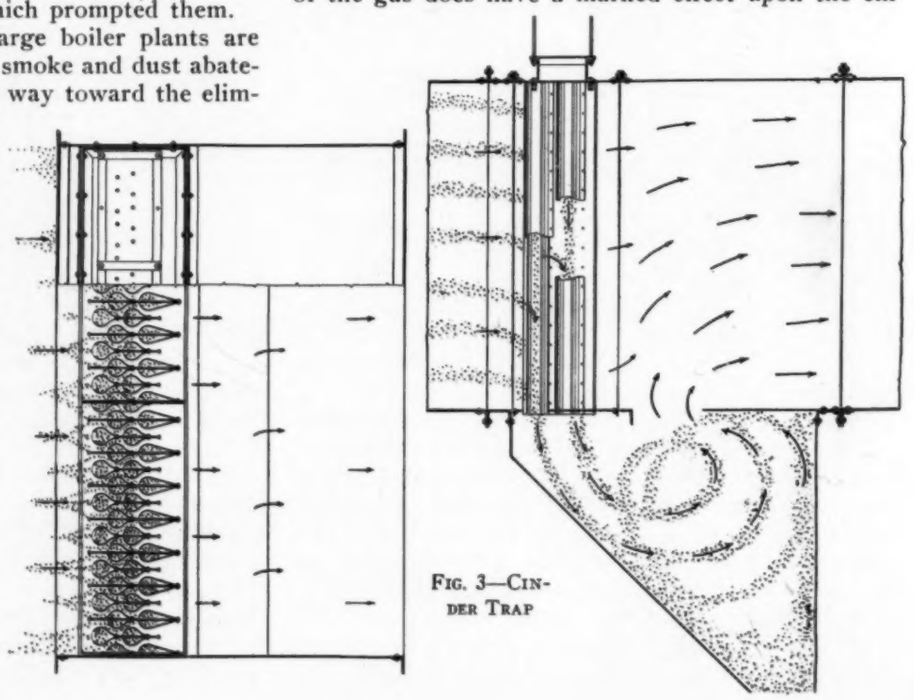
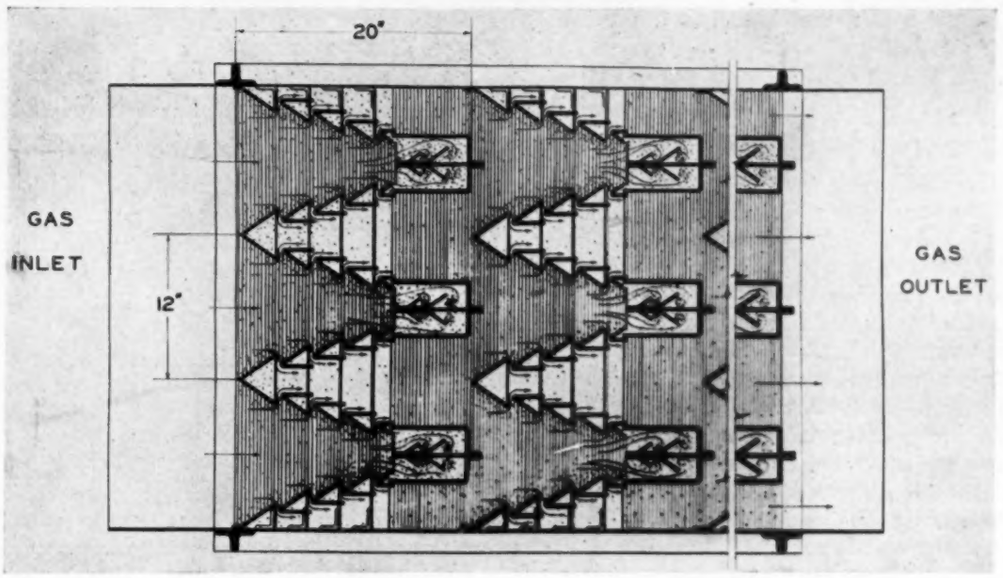


FIG. 3—CINDER TRAP



ciency of some designs. The following descriptions of several different designs are offered without reference to which was developed first.

Fig. 2 shows a dust catcher designed for installation in vertical ducts or over boiler outlets. As can be seen from the illustration, the gases are subjected to an abrupt change in direction and the dust is deposited in the center chamber from which it can be removed by gravity by means of spouts.

Another company offers the cinder trap shown by Fig. 3. This equipment divides the gases conveying the cinders into thin vertical sections and subjects these vertical strata to several abrupt changes in direction, as illustrated. The cinders are caught in the heart-shaped elements and are conveyed downward by gravity and a small stream of the gas to the hopper below. The cinders are deposited in the special-shaped hopper and the small quantity of conveying gas is released by this hopper into the main gas passage. By splitting up the gas into the narrow strata, the particles of dust are only required to pass through a very thin strata of gas to the collecting elements. These traps have proved very effective for cinders of relatively large size. The manufacturer offers this type especially for stoker-fired installations.

The same company has under development a dust trap for pulverized fuel fly ash that seems to have possibilities. An illustration is not available, but in general the gas is split up into thin vertical strata by a series of barbed and corrugated plates suspended over dust hoppers. The corrugated plates form alternate nozzles and expansion chambers. In the passage through the apparatus, the dust is blasted against the barbed surfaces to which it adheres. The barbed plates are set in groups forming sections approximately two feet wide. At intervals the sections are closed off by automatic dampers and the dust is shaken off by automatic rappers into the hopper below. This trap is under development, and further details are not available at this time.

A New York company manufactures the dust trap shown by Fig. 4. They claim to concentrate and separate the dust by creating free spiral verticose. Inverted **V** elements as shown are supported above a dust hopper. The number of elements in the path of the gas is varied from three to seven, depending upon the fineness of the dust to be collected, and the number of units in width and height is varied to accommodate the quantity of gas to be handled. A small quantity of gas flows downward into the hopper as a conveying medium and automatic rappers help to dislodge the dust which collects on the plates. The hopper is maintained in a quiescent state, and the dust is settled out from the small quantity of gas which enters the hopper as a conveying medium.

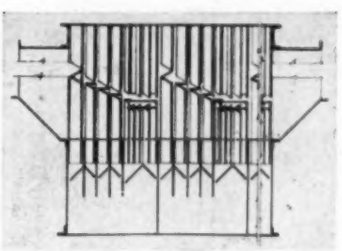


FIG. 4—CINDER CATCHER (Vorticose Type)

Another New York company manufactures barbed-plate type dust collectors. Fig. 5 shows how the barbed and corrugated plates are sometimes arranged on a horizontal shaft. As the shaft is slowly rotated, certain portions of the plates are always in a quiet chamber while the gas flows through the other plates on the shaft. The plates in the quiet portion are vibrated and the dust removed. For large gas quantities, the elements are suspended above dust hoppers in a steel casing, and the sections are closed off for rapping by means of dampers. The machines are built on the unit principle, and the size and number of units is varied to meet the conditions of a particular installation.

A number of attempts have been made to design pulverized fuel-fired furnaces in such a way as to catch a larger percentage of the dust than is normally caught. Nothing has been developed that would indicate that such a design would make it unnecessary to install other apparatus, but some such design might

well catch the larger particles of ash. Most of those tried so far have wet bottoms where the ash is maintained in a molten state and tapped off the same as blast furnace slag.

Centrifugal Catchers

Many types of centrifugal collectors have been used with considerable success. Fig. 6 shows the ordinary *garden variety* of cyclone separator which is used so extensively for separating solid matter of many kinds from air or gas. All of these centrifugal collectors obtain dust separation by projecting the particles tangentially out of the gas stream. The effectiveness of these collectors varies directly as the specific weight of the dust, and as the square of the tangential velocity, and inversely as the radius of rotation. The type of collector shown is effective for heavy dust of appreciable size but has proved entirely inadequate for such dust as carried in the flue gases from coal-fired furnaces.

Fig. 7 shows a modified form of cyclone catcher that will catch a large amount of cinders from stoker-fired boilers, but fails to catch the extremely fine dust. The dust is concentrated in the outer layer of gas, and the inner layer is allowed to escape to the outlet, as indicated by the arrows. The outer layer of gas in which the dust has been concentrated continues to the bottom of the collector and is discharged through the bottom of the outlet tube. The straightening vanes shown in the main gas outlet reduce the spin in the outlet pipe and thereby reduce the pressure loss through the apparatus.

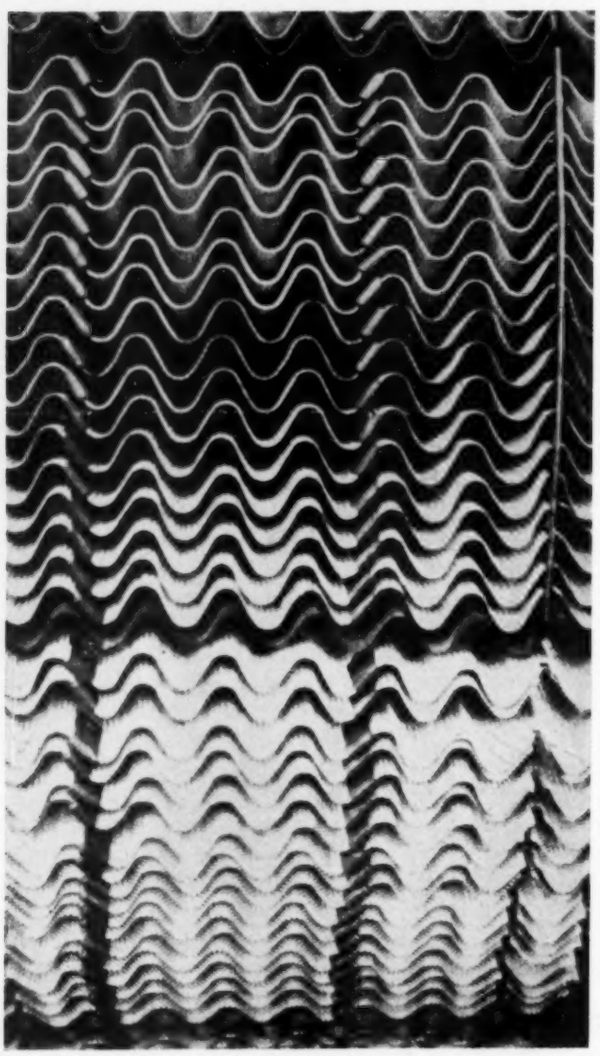


FIG. 5—BARBED-PLATE CATCHERS

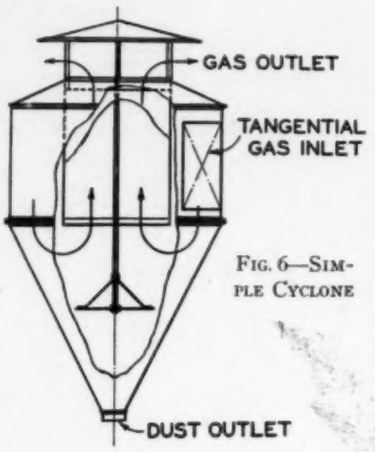


FIG. 6—SIMPLE CYCLONE

Fig. 8 shows another modified form of cyclone collector. This collector consists of a main casing of volute shape through which the dust enters tangentially. Beneath the volute, a series of alternating truncated cones and cylinders are arranged terminating in a dust outlet at the bottom. The gas is discharged through a central opening in the top of the main casing or through this opening into a scroll-shaped outlet head. The manufacturer claims that the design creates a cyclone action without internal turbulence.

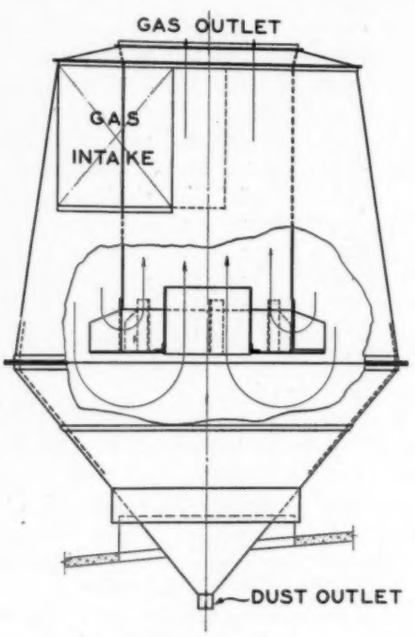


FIG. 7—MODIFIED CYCLONE

The dust-laden gas entering the collector tangentially is forced by its velocity to take a path following the shape of the volute. The dust particles are forced outward against the periphery. In addition to moving centrifugally outward, the dust is forced downward and leaves the volute in a downward direction following a spiral path which is directed and increased in velocity by the alternating truncated cones and cylinders to the dust outlet at the bottom.

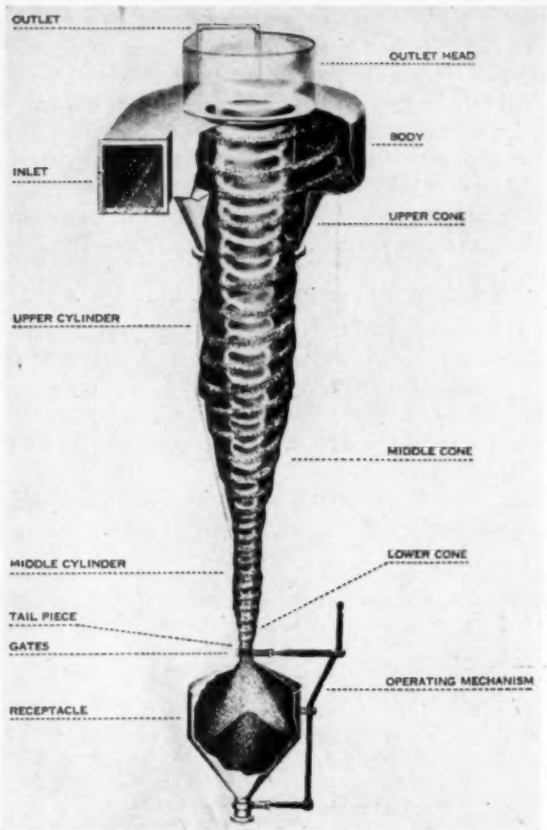


FIG. 8—MODIFIED CYCLONE CATCHER

The gas forms a vortex in the center of the collector and passes upward through the outlet.

An English company manufactures the collector shown by Fig. 9. This collector consists of a number of triangular shaped volutes arranged side by side above a gas-tight dust hopper. Slots are arranged in the apex of the volutes to allow the dust to enter the dust hopper along with a small percentage of the gas. The dust is settled out of the conveying gas in the dust hoppers and the gas is returned to the main gas passage.

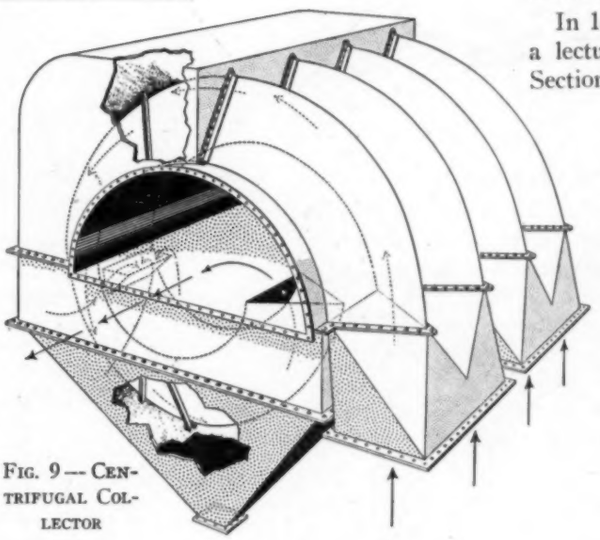


FIG. 9—CENTRIFUGAL COLLECTOR

Another centrifugal collector is shown by Fig. 10. As can be seen, this collector consists of two horizontal concentric cylinders. The gas is admitted tangentially through the outer cylinder at one end into the space between the two concentric cylinders, and leaves through the center of the inner cylinder at the opposite end. In this manner the gas is given a spin, and the dust is thrown out through slots in the outer cylinder into a suitable gas-tight hopper.

A number of attempts have been made to make the induced draft fan act as a dust separator. Fig. 11 shows one of these designs. The cut clearly shows the separating action that takes place. The gas containing the cinders enters the inlet of a paddle-wheel fan, the blades of which are provided with channels to catch and direct the cinders into the chambers in the sides of the casing. This fan makes use of the sudden changes in gas direction and velocity that occur in all paddle-wheel type fans to separate the cinders from the gases.

A cinder-eliminating fan is shown by Fig. 12. In this fan advantage is taken of the concentration of dust due to centrifugal action in the layer of gas next to the scroll of the fan. Openings are provided in the bottom part of the scroll and a gas-tight dust hopper is arranged below the fan to collect the dust discharged through the openings in the scroll.

Another cinder collecting induced draft fan is shown by Fig. 13. The involute of the fan is prolonged to concentrate the dust and from 5 to 15 per cent of the gas is drawn off and the dust separated from it by means of a comparatively small cyclone collector. The gas discharged from the small cyclone is returned to the inlet of the fan. One or more cyclones are installed, depending upon the dust collecting efficiency desired and the character of the dust to be separated.

All of these centrifugal devices have the serious problem of erosion to overcome, and the space requirement is often embarrassing. The advantages of this type of equipment are obvious.

Electrostatic Precipitators

In 1886, Sir Oliver Lodge in a lecture before the Liverpool Section of the *Society of Chemical Industry* pointed out the possibility of separating dust and vapor from gases by electrical means. In 1903-1904, Dr. F. G. Cottrell became interested in the Lodge experiments and applied the principles to the precipitation of sulphuric acid mist. After years of experimentation, he produced a successful electrostatic precipitator. Electrostatic pre-

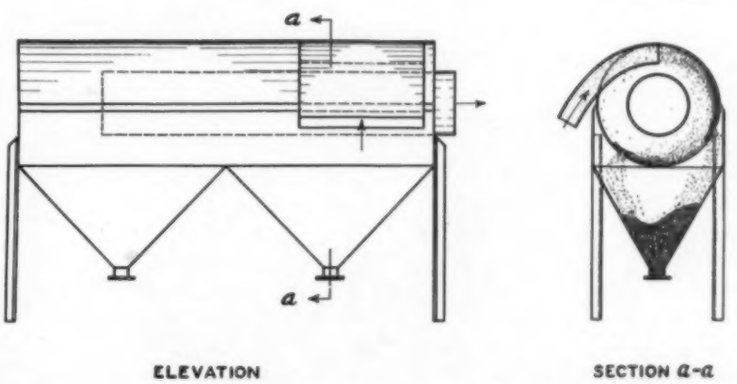


FIG. 10—CYLINDRICAL COLLECTOR

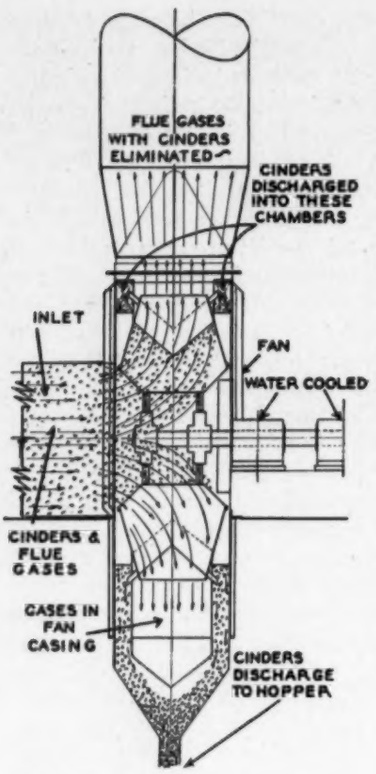


FIG. 11—CINDER-CATCHING FAN

for the precipitation of fly ash from the gases of pulverized fuel-fired boilers was developed at that plant.

The precipitators consist of gas-tight chambers in which are suspended vertically, concrete slab collecting electrodes parallel with each other, as shown in this figure. The concrete electrodes are two inches thick and have imbedded in them steel reinforcing rods which act as the positive electrodes. The plates are spaced 10 in. apart, center to center, and in the space between are suspended bare rods as negative electrodes. Alternating current at 75,000 volts is rectified by a mechanical rectifier to supply unidirectional current to the electrodes of the precipitators.

This high potential ionizes the dust-laden gas as it passes through the precipitator and causes the dust particles to take on a high potential charge. An electrically charged particle under these conditions tends to move toward the negative electrodes or the concrete slabs in these precipitators. The dust clings to the concrete slabs until it builds up to a thickness that will cause it to drop off due to its own weight into the dust hoppers provided below. The precipitators are divided into sections and each section is provided with suitable dampers so that sections can be closed off and the dust scraped off the concrete slabs, if necessary, while the other sections are in operation. The efficiency of this type of dust catcher varies with the dust loading, size of the dust particles, and the time that the dust-laden gas remains in the catcher.

cipitators have been installed in a number of plants in the United States for catching the fly ash in the gases from pulverized coal-fired furnaces.

Figs. 14a, 14b and 14c show the design of and efficiency curve for the electrostatic precipitators installed at the Trenton Channel Plant of the Detroit Edison Company. The present design used

Gas Scrubbers

The dust in boiler flue gas has been successfully removed by means of gas scrubbers. Fig. 15 shows the inside of a gas washer installed for removing the dust from the gases of a pulverized coal-fired boiler in the Calumet Station of the Commonwealth Edison Company of Chicago. This scrubber consists of one set of sprays and a set of eliminator plates with flooding nozzles for washing the dust from the eliminator plates.

The big problem in developing a satisfactory wet dust catcher is to find materials that will resist the corrosive action of the wash water. The water from these scrubbers contains sulphuric and sulphurous acids and very few suitable materials are available that will resist the action of the latter for a reasonable length of time.

A number of European plants have installed sprays in the chimneys of the boiler plants and report suc-

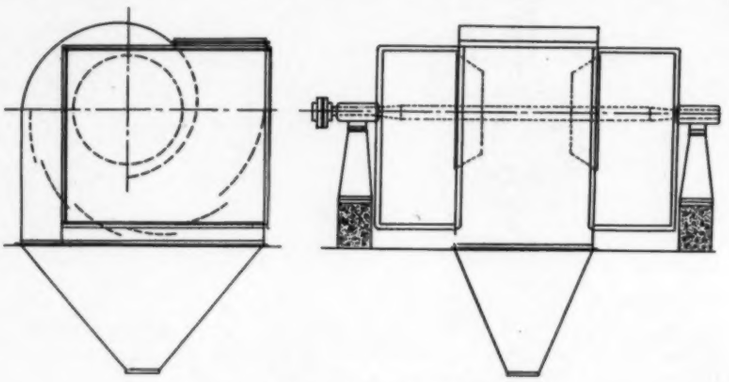


FIG. 12—CINDER-ELIMINATING FAN

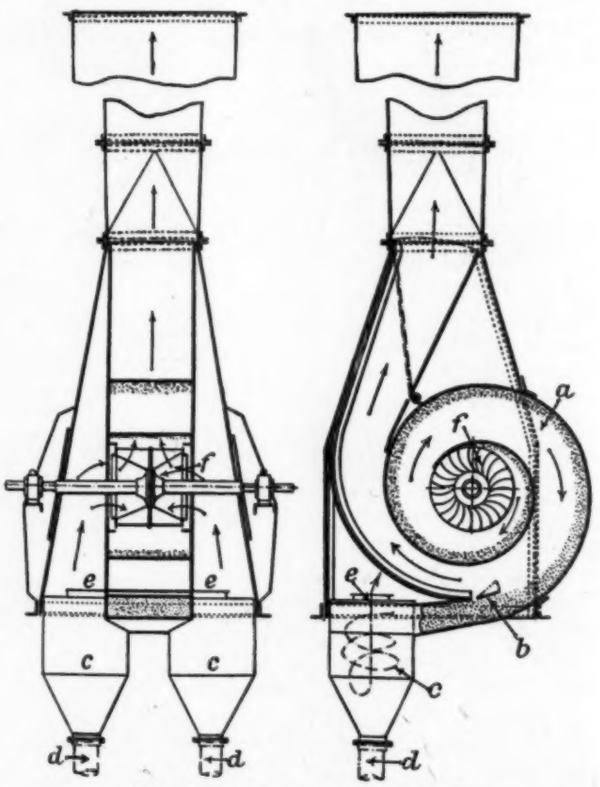


FIG. 13—CINDER-COLLECTING FAN

cessful removal of the dust. The problem here would seem to be to prevent discharging acid water particles from the top of the chimney. A very low gas velocity will convey the smaller water particles and it is necessary that this possibility be eliminated before this scheme can be adopted generally.

Fig. 16 shows a vertical type of scrubber that has been used for blast furnace gas. As can be seen, the scrubber consists of a vertical shell with a gas inlet at the bottom and a gas outlet at the top. Inside the shell are a number of baffles and troughs which cause the gas to flow through a number of water sprays. The water sprays are provided by a rotating, multiple cone water atomizer and also by the streams of water dropping from the upper baffles to the lower.

Fig. 17 and Fig. 18 show the two types of vertical scrubbers installed in the new Kneeland Street steam heating boiler plant of The Edison Electric Illuminating Company of Boston, Massachusetts. Fig. 17 shows the design that utilizes the revolving disc atomizer. The gas is admitted tangentially at the bottom so as to give the gas a spin and is released at

Fig. 15—Simple Gas Washer

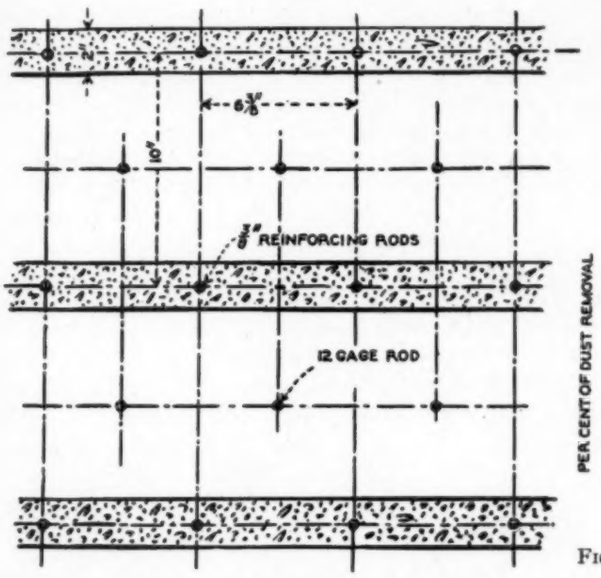


Fig. 14A—Plan Showing Details of Electrostatic Precipitator Construction

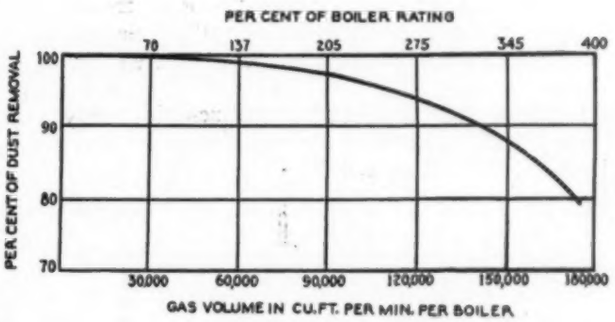


Fig. 14C—Typical Efficiency Curve for Electrostatic Precipitator

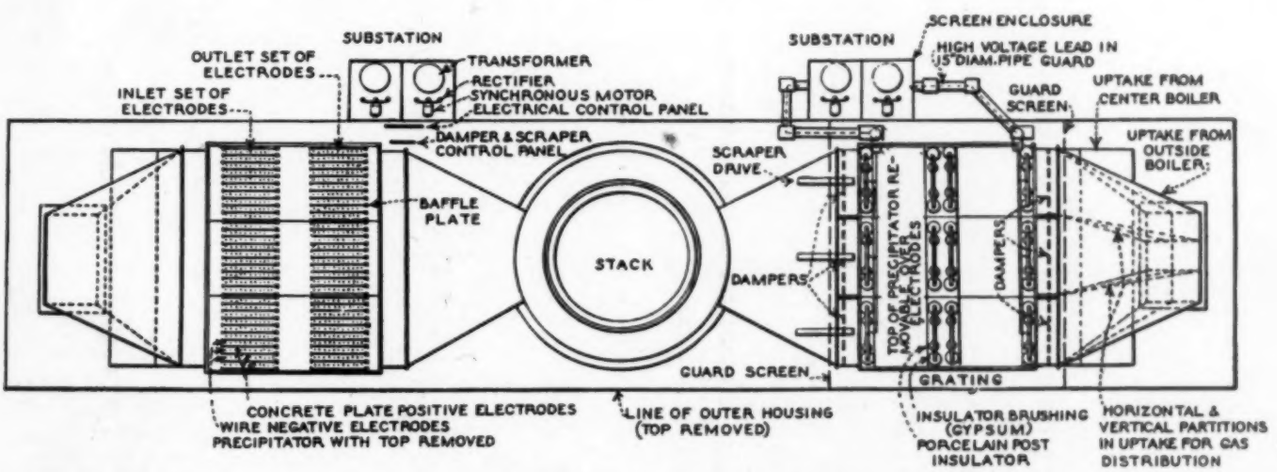


Fig. 14B—Plan Showing Relation of Electrical Precipitators, Electrical Equipment, Stacks, Etc.

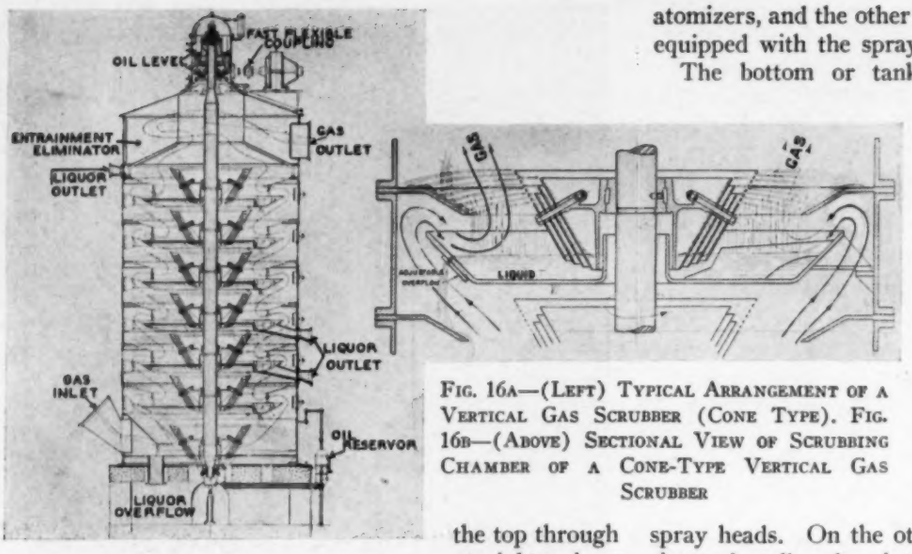


FIG. 16A—(LEFT) TYPICAL ARRANGEMENT OF A VERTICAL GAS SCRUBBER (CONE TYPE). FIG. 16B—(ABOVE) SECTIONAL VIEW OF SCRUBBING CHAMBER OF A CONE-TYPE VERTICAL GAS SCRUBBER

the top through straightening vanes which iron out the spin of the gas and reduce the pressure drop through the scrubber.

The bottom of the scrubber forms a tank for the collection of the dust and water. A certain quantity of water is drawn off continuously to remove the dust and the remainder of the water is recirculated as the scrubbing medium. By spinning the gas with the tangential inlet the larger particles of dust are thrown out more readily by centrifugal action, and the water particles are thrown through the gas stream. Furthermore, the gas spin throws out all water particles and discharges moisture-free saturated gas from the scrubber.

Fig. 18 shows the design that utilizes the spray head type water atomizers. One boiler in the Kneeland Street plant is provided with the scrubbers equipped with the revolving disc atomizers, and the other boiler is provided with scrubbers equipped with the spray head type atomizers.

The bottom or tank portion of each scrubber is lined with lead and the bottoms and shells are protected with a lining of acid-proof brick laid in acid-proof mortar. The discs, spray heads, and struts are constructed of special acid-resisting metal. Other parts are of cast iron painted inside with an acid-proof paint and protected on the outside with an acid-resisting plastic material.

The rotating disc type of water atomizers undoubtedly give a finer spray than the spray heads. On the other hand, they are more expensive to install and maintain. The Kneeland Street plant installation in Boston should tell whether the more expensive atomizing device is necessary.

Fig. 19 shows an English design of gas scrubber. As can be seen from the cut, the gas is admitted at the bottom and released at the top of a cylindrical shell. Inside the shell are arranged two sets of sprays which are operated continuously, and two sets of baffles. Above the top set of baffles is installed a set of flushing sprays for periodically flushing off the baffles. The water is drained away at the bottom.

Fig. 20 shows a gas scrubber which differs radically from the types of scrubbers described previously. In this scrubber the shell is rectangular and the gas flow is horizontal. Inside the shell are arranged large numbers of closely spaced pipes, rectangular in shape, which are closed at the bottom and

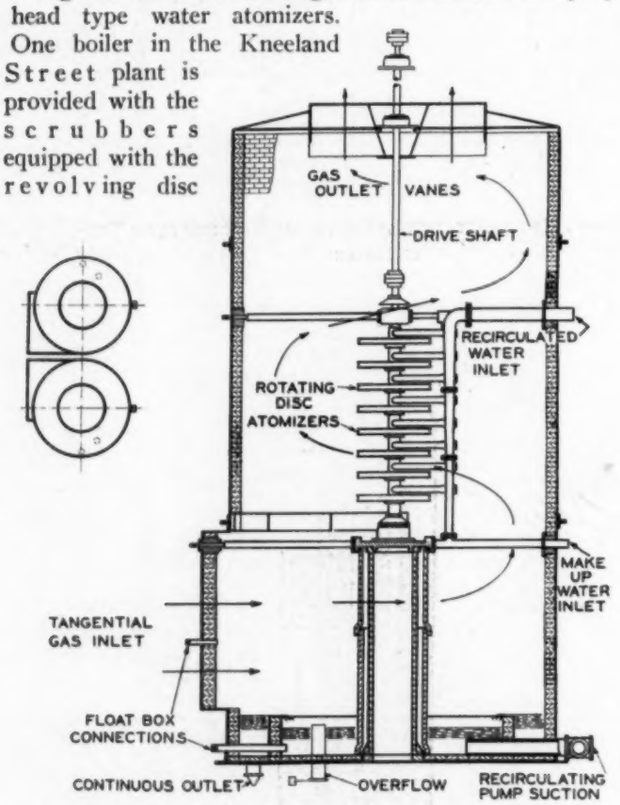


FIG. 17—VERTICAL GAS SCRUBBER (DISC TYPE)

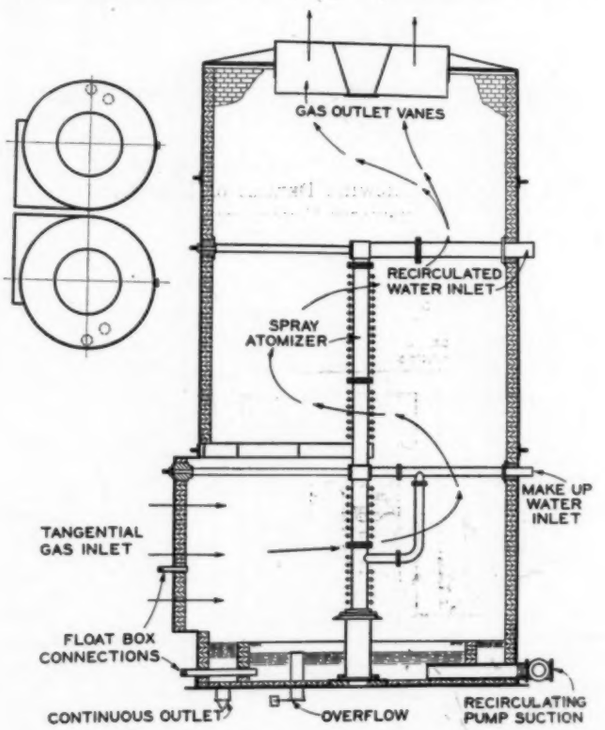


FIG. 18—VERTICAL GAS SCRUBBER (SPRAY TYPE)

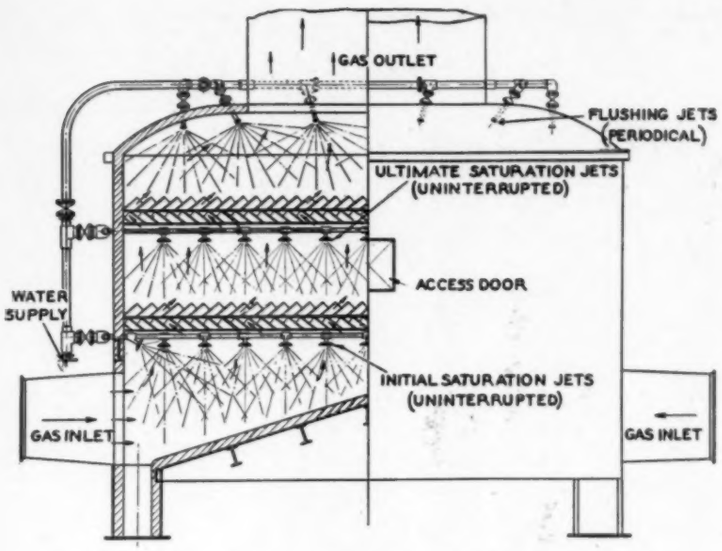


FIG. 19—ENGLISH GAS WASHER

open at the top. Water is admitted through calibrated orifices into the top of the vertical pipes and overflows and keeps the outside of the scrubber pipes wet with a film of water. The gas is split up into thin vertical sections as it passes through the scrubber, and these vertical strata are subjected to several abrupt changes in direction. The dust is impinged against the wet scrubber pipes where it is caught and carried away to the sump below which removes the water and dust. By splitting the gas into the narrow strata, the particles of dust are only required to pass through a thin strata of gas to the collecting elements, the same as in the case of some of the dust traps. The water prevents the re-entrainment of the dust particles, and the water that is evaporated increases the relative humidity of the gas and aids in the separating action.

Filters

Filters of various kinds have also been tried with considerable success. Fig. 21 shows a type of fabric filter. The cut shows a very small filter, but the same design is applied in filtering the dust from boiler flue gases. The dust-laden gas is admitted at the bottom of the gas-tight casing and is filtered through bag-type fabric filters of cotton, wool, or asbestos cloth, depending upon the temperature of the gas to be filtered. The filters are made in units so that individual units can be shut off with dampers and the bags shaken to remove the dust collected on the bags. In Fig. 21, the unit at the left is in operation while the unit at the right is being cleaned.

Fig. 22 shows a gravel filter now in the process of development. In this filter, gravel is used as the filter medium and is removed continuously at the bottom, screened to remove the dust, and returned to the filter at the top.

Practically all of the dust catching devices described are in a state of development, and it will probably be many years before the most satisfactory types are determined. It should be noted, however, that only the wet scrubbers make any attempt to catch the noxious gases.

The development of these and many other types of dust catchers clearly shows the general interest in the subject and the tremendous amount of research and development work that has already been done. Undoubtedly, within a few years, satisfactory and commercial equipment will be made available.

One of the embarrassing features of the subject is that after a dust catcher has been installed it is extremely difficult to tell exactly how thoroughly it is doing its work. The methods of test are many and each will give a different answer. The manner of conducting the test can vary the answer to suit the convenience of those responsible for the conduct of the test. There is a serious need for a standardized test code for dust collectors. Even though it may not be perfect, if it will only give comparable results for the various tests in various plants, it will help immensely.

A very simple test would be advisable at this stage of developments, so that a large amount of comparable test data will become available in the shortest time possible. A code calling for a standardized test by means of standardized fabric filters would be useful, and would result in the collection of data that would be extremely valuable in the development of the art of dust catching. It is to be hoped that the formulation of such a code will be undertaken in the near future.

Noxious Gases

The third subdivision of the subject is the pollution of the air by noxious gases which are harmful to animal and vegetable life and to building materials.

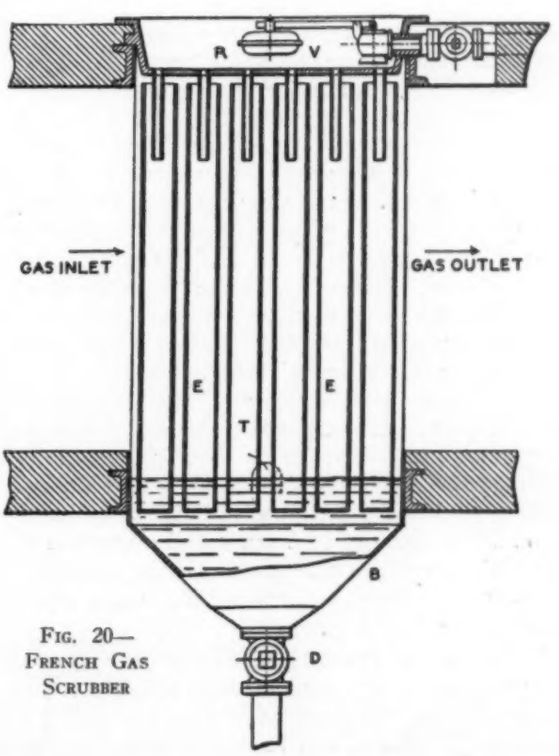


FIG. 20—FRENCH GAS SCRUBBER

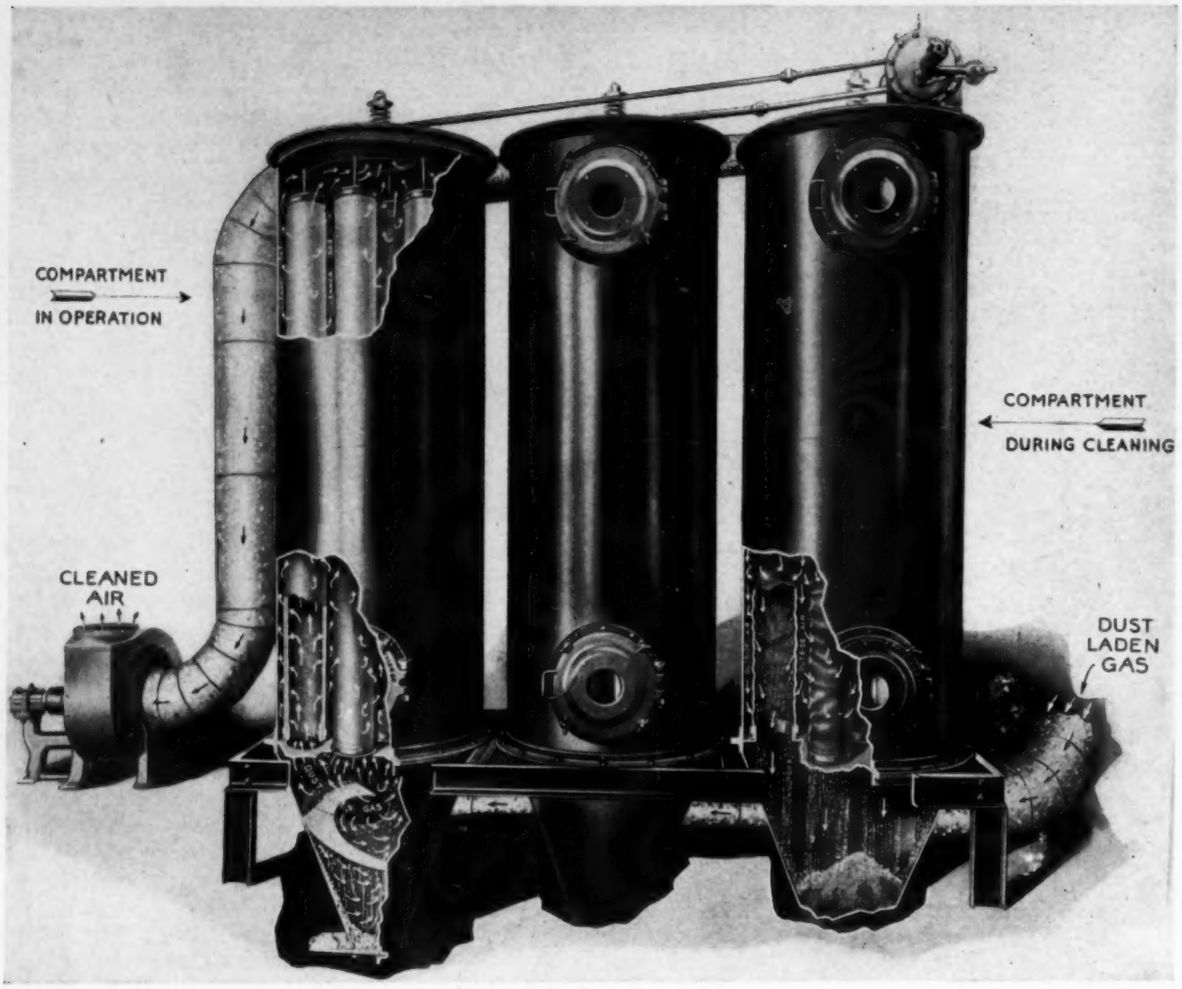


FIG. 21—FABRIC FILTER

There is no question that the discharge of active gases of this nature to the atmosphere must be stopped. Those industries which have to deal with poisonous gases have already had to take steps to neutralize the gases discharged. It is not helping the problem, however, to believe the articles published which paint extremely gloomy pictures of the damage done by the gases discharged from the chimneys of properly designed and properly operated boiler plants. Disregarding the question of smoke and dust, the only noxious gases discharged from such boiler plants are the sulphur gases resulting from the combustion of the sulphur in the fuel. Where high-sulphur coals are burned, the problem may become serious enough to justify going to some length to neutralize the sulphur gases, but where the sulphur content of the fuel is less than 2 per cent, it would be extremely difficult to trace any appreciable damage to human and vegetable life or to building materials to the discharge of such gases to the atmosphere at a reasonable height above the surrounding buildings.

Where a real problem of this nature exists, however, a satisfactory answer seems to be available. A gas scrubber of the proper design, utilizing the proper scrubbing medium, will remove a large part of such

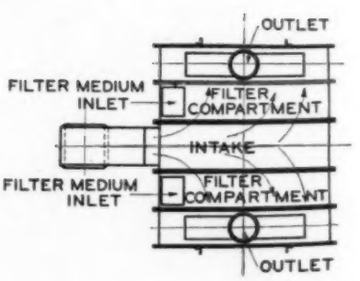
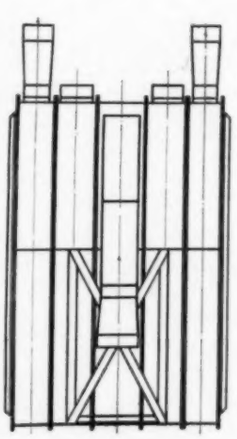
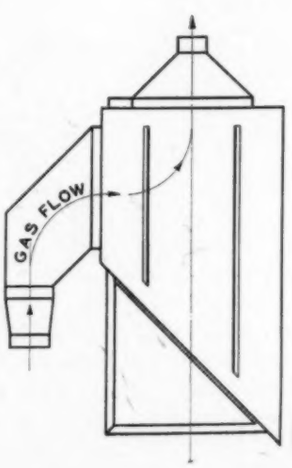


FIG. 22—GRAVEL FILTER





noxious gases. If the gas scrubber should finally prove to be the proper equipment for the catching of the dust, it should not be difficult to make that scrubber also serve to absorb the sulphur fumes.

The effects of atmospheric pollution have been classified as medical, botanical, and physical. A great deal has been written about the effect upon human health, vegetable life, and the deterioration of inert materials. In some cases an attempt has been made to reduce the harmful effect to dollars and cents. Such figures are absurd and it certainly is unwise to build up hypothetical figures without a reasonable basis in an effort to frighten those unfamiliar with the subject, or to create a state of panic which might result in inadvisable legislation. The problem is really a serious one but as pointed out by A. S. Langsdorf, Director of Industrial Engineering and Research of Washington University, St. Louis, a great deal more information must be collected at numerous stations over wide areas at frequent intervals and over an extended period of time before any definite conclusions can be drawn. These data should be studied carefully in connection with health and other pertinent statistics and in co-operation with the medical profession.

Without intending to make light of so serious a subject, attention is called to the fact that without atmospheric pollution animal and vegetable life would not be possible upon this earth and some of the most awe-inspiring sights of nature would never occur. Without dust in the air to form the nuclei for rain drops, the entire earth would be constantly surrounded with enormous clouds of vapor, but it would never rain, and the beautiful sight of a rainbow would never exist. Without dust there would be no beautiful sunrise or sunset, and the northern climes would never know the wonders of the Aurora Borealis. Of course, the dust produced by nature would be sufficient to produce all these blessings and wonderful sights, and it would be desirable if domestic and industrial life could be so conducted that it would not add to the pollution of the air. These facts have been pointed out in order to counteract to a small degree the publications of extremists who desire to hold up the question of atmospheric pollution as a kind of bugaboo.

The more progressive companies are keenly alive to the need for a reduction of air pollution. They are bending every effort of science, research, and experimentation toward the elimination of their part of the nuisance. If the records of past accomplishments are any indication of future progress, success will be achieved within a comparatively few years.

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Appearance Factors in Engineering Graphs[a]

Certain principles relating to the graphic arts control the effectiveness of a graphical presentation. Our discussion is to outline some of these principles, the part played by line weights, size, proportion and unity between the elements of a chart, all of which are involved in the process of putting engineering and scientific information into effective and attractive form.

A graphical illustration used in a scientific or engineering journal usually has as its purpose the efficient presentation of an idea or a relationship. It is capable of flashing a complete relationship to the reader's mind, something that cannot be done by lengthy phrases or sets of cold numbers. Everything that passes before the eye produces a reaction on the mind, either attractive or repellent. The effect in the one direction or the other may be very small indeed, but much is to be gained by making the initial reaction a favorable one. Engineering and scientific graphs are no exception.

Reproductions in the printed article should be in keeping with the background furnished by the associated typed matter. Neither shouting nor whispering will be effective; instead the general emphasis or grayness should be such as to create the impression that the graph speaks in a firm and convincing tone.

The central thought should receive the greatest emphasis; all else is necessary background and should be given degrees of emphasis consistent with relative importance. The end result should be a graph whose appearance is one of unity, no element demanding attention out of proportion to its importance as a part of the assembled whole.

[a] Summary of paper by H. F. Dodge of the Bell Telephone Laboratories, at a meeting of Subcommittee No. 6 of the A.S.M.E. Sectional Committee on Graphical Presentation, Dec. 4, 1930.

Air Conditioning in the Bakery

By W. L. Fleisher[1], New York
MEMBER

THERE is no doubt that air conditioning is essential to bread-making because in some simple manner temperature and moisture have been an essential part of kneading, fermentation and baking of bread since primitive times. But the writer has been forced to change his ideas drastically as to just what air conditioning does do in a bakery, after a thorough investigation of the basic electrical and chemical laws which underlie this subject. The industrial application of air conditioning to any field revolves principally around moisture regain and static electricity. Probably there is more connection between these two factors than the air-conditioning engineer has suspected. While the conditions required for the production of a good loaf of bread are generally known, it is not entirely obvious as to why these conditions have the effect that they do. It is probable that the treatment of bread is almost entirely a surface problem, and consequently the air-conditioning equipment for bakeries which has been designed (as most of it has been) to deal with the entire bulk either of the flour, the dough or the loaf is not only unessential, but possibly deleterious to production. This probably explains the reasons why the simple methods of conditioning which were part of the bread-making art for so many centuries and which consisted principally in maintaining a suitable temperature for fermentation or the retarding of fermentation, and such simple expedients as dampened cloths, etc., which were used to cover the doughs during the fermentation period, were so efficacious, because only the exposed surfaces of the doughs and the breads were affected by exterior conditions, when the time element was taken into consideration.

Bread is essentially a combination of wheat flour and water to which has been added salt, yeast, sugar, malt extract, milk and shortening. The average batch of bread contains the following amounts of various ingredients: flour, 300 lb; water, 180 lb; salt, 5½ lb; sugar, 7 lb; malt extract, 3 lb; yeast, 6 lb; shortening, 6 lb; milk, 7 lb. The percentages of each of the ingredients to the whole batch is the result of hundreds of years of experimentation to obtain satisfactory results.

It has been stated that industrial air conditioning has principally to do with the regain of moisture. In other words, that there is a set moisture content for every hygroscopic material which follows the line or curve of relative humidity; that with a change in the relative humidity, the hygroscopic material loses or gains moisture and that equilibrium is established when the vapor pressure of the atmosphere surrounding it equals the vapor pressure of the hygroscopic material. Air conditioning authorities have even followed this line of reasoning in connection with dough and bread, but it does not apply where the substance treated to a bath of conditioned air is in a colloidal state. Consequently the behavior of doughs and bread and even the flour, which is the main constituent in dough and bread, does not follow this reasoning, as the flour itself, to a more or less degree, is in a colloidal state from its own moisture content, which it holds and retains from the wheat berry.

Hydration Process in Modern Baking

As bread-making is to a large extent a hydration process, and as the actual moisture content is little affected by the surrounding atmosphere, there may be some question as to why air conditioning is so essential. The modern machine bakery consists of a flour storage department in which the flour, either in sacks or barrels, is stored for considerable time. It has been shown by innumerable tests that a temperature of about 78 F and a relative humidity of 70 per cent are very satisfactory for the storing of flour. Under these conditions, flour will retain about 13 per cent water by weight. However, if flour is dried for several hours at a temperature as high as 212 F with a correspondingly low relative humidity, the flour still retains 11 per cent or thereabouts of moisture by weight.

The problem of moisture in flour is further complicated by the fact that the water is united to the solid particles in varying degrees of affinity and also by the fact that there are two kinds of moisture in flour, sometimes called *moisture of constitution* and *moisture of wetness*. The moisture of wetness is the moisture which adheres to the surface of the flour particles and is purely physical. Violent heat will very quickly vaporize, disperse and drive off this water, leaving the flour itself more or less unaltered. The moisture of constitution, which is really water of hydration of the swollen protein particles, is of major effect in determining the useful properties of the flour. This moisture is held by a physiochemical attraction, and if or when removed the properties of the proteins will be completely changed, although the chemical compositions remains unaltered.

Seemingly, therefore, air conditioning of the flour storage has to do simply with this one or two per cent of surface moisture, rather than the important chemical-affinity water in the protein. Fig. 1 shows graphically the conditions of temperature and relative humidity, conditions which over a period of years have proved most satisfactory to the bakers. The question therefore arises as to whether these conditions are not necessitated or recommended because of the very method of producing them, and whether air conditioning in the bakery should not be separated into its various subdivisions of temperature, moisture content and air movement, in order to determine whether each of these may not be

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Presented at the 37th Annual Meeting of the American Society of Heating and Ventilating Engineers, Pittsburgh, Pa., January, 1931.

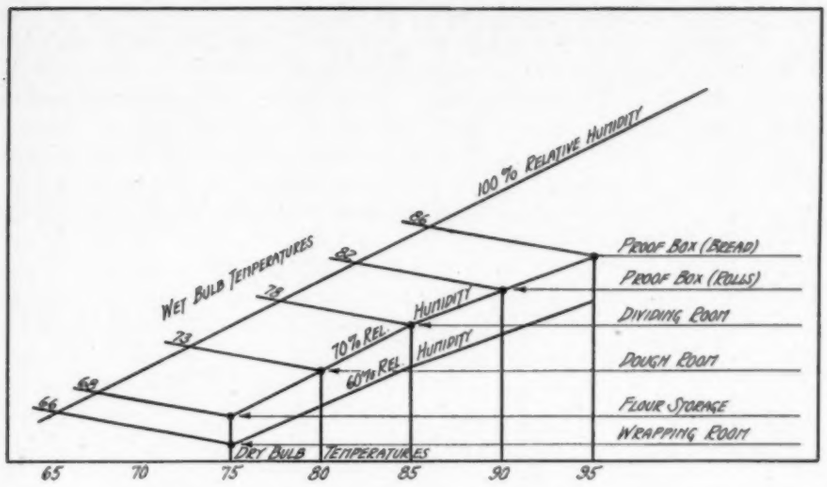


Fig. 1—Psychrometric Chart for Bakery Conditions

adversely affecting the other, the results being a wasteful method of improvement.

In order to appreciate the hydration problem in a bakery—and it is, after all, to preserve this hydration that air conditioning is advocated, or at least it is for this reason that it has been advocated up to this time—it is necessary to understand the chemistry of flour. It is the reaction of the various elements in their molecular state which go to make up the wheat berry and the resulting flour, which so profoundly affect the moisture retention possibilities of flour, and eventually of the dough. It is essential, in fact, in order to balance the results, to understand the chemistry of colloidal behavior and the action of electrolytes in order to fully appreciate the value of air conditioning in the bakery.

An investigation of moisture loss or gain from the flour to the finished loaf in the light of the colloidal retention of moisture would lead one to believe that the moisture change which takes place throughout the bread making process cannot possibly be anything except a surface condition.

Hydrogen-ion Concentration

The most important basic principle in the making of bread as determined by scientists who have investigated this problem from the chemical and physical standpoint is the hydrogen-ion concentration. The writer feels that without a thorough knowledge of hydrogen-ion concentration and its effect on the starch, the gluten and the fermentation itself, a true knowledge of the effect of air conditioning on bread-making cannot be attained. An explanation of acidity and hydrogen-ion concentration should therefore prove helpful.

The acidity of a solution, which is denoted by the symbol pH, depends upon the concentration of hydrogen-ion derived from the dissociation of the substance in solution into its component ions. By hydrogen-ion concentration, denoted by the symbol H, is meant the concentration of hydrogen-ion expressed in grams equivalent weight per liter of solution. By the pH of a solution is meant the hydrogen-ion concentration in grams equivalent weight expressed as the log to the base 10 of its reciprocal or, in other words, the negative log of the hydrogen-ion concentration with the negative sign omitted. Sorensen found that if the hydrogen-ion concentration of a solution is determined by means of a hydrogen electrode, the equation reduces to

$$\frac{\text{Potential}}{\text{numerical factor}} = \log \frac{1}{H} \quad (1)$$

and he introduced this method of designating hydrogen-ion concentration. The pH of a solution thus designates the intensity of the acidity and not the concentration of the total available acid. One may state that the pH is the measurement of the voltage rather than of the amperage of the acidity.

To further illustrate the difference between concentration of total acid and acidity, one must first define the meaning of the term *normal solution* which is one of the terms used by the chemist to express concentrations. A normal solution is a solution which contains one equivalent weight of the solute in one liter of solutions. By equivalent weight is meant that weight in grams of an element or substance which will react with 8 grams of oxygen to 1 gram of hydrogen. Thus the formula weight of hydrochloric acid (HCl) is 36.5 and this is also its equivalent weight. The formula weight of sulphuric acid (H_2SO_4) is 98.08 and this contains two equivalent weights. The normality of a solution is expressed by $\frac{W}{E}$ where W is the weight in grams of the substance in one liter of solution and E is the equivalent weight of the substance.

The strength of the acid depends on the degree of dissociation which furnishes the hydrogen-ion. Hydrochloric acid belongs to the group of strong acids. It is highly dissociated in the more dilute solutions. In a 0.1 normal solution the HCl is 92 per cent dissociated, hence in such a solution there are 0.092 grams of H-ion per liter of solution. The pH of this solution is the log of $\frac{1}{0.092}$ or 1.04. The hydrogen-ion concentration H is written 9.2×10^{-2}. Diluting this 0.1 normal solution so as to obtain a 0.00001 normal solution a hydrogen-ion concentration H of 9.2×10^{-6} and a pH of 5.04 is obtained.

With a 0.1 normal solution of acetic acid (equivalent weight, 60) a hydrogen-ion concentration of 0.13×10^{-2} is obtained, as acetic acid is a weak acid and its dissociation in that dilution is only 1.3 per cent. The pH of a 0.1 normal acetic acid solution is 2.9, while the pH of a 0.00001 normal acetic acid solution is 6.9, practically at the neutral point. This explains why a 0.1 normal solution of acetic acid is of the acidity of ordinary vinegar, while a 0.1 normal solution of HCl would be caustic to the taste.

The point of neutrality mentioned lies at pH 7. Pure water will conduct an electric current and is therefore slightly ionized, and will furnish ions for the conduct-

ance of the current. Water (H_2O) may be written HOH and it is slightly dissociated into positive H-ions and negatively charged OH-ions. Since it furnishes the same number of H-ions which are acidic in character as OH-ions which are basic in character, it is neutral in reaction.

By the law of mass action which covers chemical equilibrium, the relation for water is $\frac{[H^+] \times [OH^-]}{H_2O} =$ K, a constant. Since the concentration of the undissociated water, even for dilute solutions up to about 0.1 normal remains fairly constant, the relation may be written $[H^+] \times [OH^-] = K_w$. The constant K_w, which is the same as K, is known as the ionization constant of water and has been determined to be 10^{-14} at 77 F, or pH 7. Any hydrogen concentration exceeding this will give acidity, while if the hydrogen-ion concentration decreases below this point, the solution will be alkaline. It must be remembered that as the numerical value of the symbol pH decreases, the acidity increases, and vice versa.

S. P. L. Sorenson, probably the outstanding cereal chemist today, states that the pH of the dough is of the highest importance in insuring good bread from an otherwise good dough and the explanation as to why the concentration of hydrogen-ions affects the quality of the bread, is explained by him from two angles. *First,* the hydrogen-ion concentration affects the enzymes of the flour and the yeast, and *second,* the physical-chemical condition of the substances in the flour, particularly in the proteins.

It has been definitely proved by authorities working on this subject that a pH concentration of approximately 5 is the best pH concentration, both for the development of enzyme action for the production of carbon dioxide and alcohol, and for the development of the gluten for the adsorption of moisture. What bearing this explanation of hydrogen-ion concentration may have on air conditioning in the bakery cannot be determined without a more thorough knowledge of the ingredients which go to make up the baked bread.

In the earlier part of this paper it was stated that flour constituted about 60 per cent of the dough entering into the making of bread. This wheat flour itself may be divided into the following proximate analysis: starch, 65 to 70 per cent; protein, 9 to 14 per cent; water, 13 to 15 per cent; cellulose and fat, 1 per cent; sugar 2½ per cent; and ash, ½ per cent. From this analysis one would assume that starch was the most important component of flour, but this is not true. During the fermentation of the dough, a small part of the starch is attacked by the enzymes and is broken down into sugar substances, which the yeast ferments.

The gelatinization of wheat starch is of importance, because in the baking a certain amount of this gelatinization takes place. Wheat starch will commence to gelatinize and swell if placed in sufficient water at 140 F, and at 149 F all the starch turns into a starch paste. It might be assumed that as the oven temperature rises to 500 F and the amount of water in the dough is approximately 40 per cent of the total weight, all of the starch in the baked loaf is gelatinized, whereas in fact, only a very few grains are gelatinized. The reason for this is that the inside of the loaf is seldom over 200 F, and the time factor is comparatively short.

It should be emphasized that the 40 per cent of water is not available as water, as the gluten absorbs a very large proportion of it. Starch is colloidal in its nature, although the colloidal properties of ungelatinized starch are not nearly as marked as those of other ingredients of flour.

Proteins

The proteins which compose 9 to 14 per cent of the flour are complex substances of large molecules built up of amino acids which contain both an acid group and a NH_2 group and therefore may behave as acids or as bases depending on the pH and owing to the size of the molecules are usually present in the colloidal state. It is these proteins which with water form the gluten which is so essential to satisfactory baking. *The colloidal character of the proteins determines the main baking properties of the flour.* It is here that the pH concentration of approximately 5 is of such great importance. Great stress is laid on maintaining certain air conditions in the bakery during the making of bread, but according to investigations that have been made not only in this country but in Europe, a slight variation in the pH concentration of the dough will affect the quality of the bread and its possibilities for retaining moisture, infinitely more than any variation in atmospheric conditions.

To entertain hope, however, of developing a solution for the need of air conditioning in the bakery or its proper application, without a description or a definition of the colloidal state, is futile. In defense of this contention, one of the great English chemists, in an article on colloidal behavior in bread-making has stated "that no manufacturer is less aware of the chemical problems underlying his trade than the master baker." If a chemist, working almost entirely in cereal chemistry may make this statement of the master baker, the writer feels that he may also state that the air-conditioning engineer is almost equally unaware of the chemical and physical problems underlying his profession, and unless the colloidal state of the ingredients entering into the manufacture of bread are understood by the air-conditioning engineer, he can never hope to solve the problem of air conditioning in the bakery.

The chemist who has made the statement about the master bakers has said that there has been no stimulus for master bakers to learn the chemistry of their trade, since in the bakery the feeling, tasting or smelling of the ingredients are better guides in the making of bread than the use of test tubes and balances. It is, however, the desire to obtain the greatest yield from the ingredients that has eventually turned the large producer of bread over to the chemist. It is, therefore, from the economical standpoint that the chemist has come into his own in the bakery, and it may be from the economical standpoint that the scientist and physicist may come to their own in air conditioning.

Briefly, all substances when in solution behave either as crystalloids or colloids. If a substance in solution is present in molecular or ionic dispersion the solution is called a true solution. The size of such particles does not exceed one millimicron. If a substance in solution forms aggregates of greater than molecular size or if the mole-

cules are very large, such as for instance, the protein molecule, the solution is called a colloidal solution and the substance may be said to behave as a colloid. The size of such aggregates varies between one millimicron to 100 millimicrons. If the size of the aggregates is still larger, so as to exceed 100 millimicrons and to be visible under the microscope, a mechanical dispersion results.

Substances in colloidal solutions may again be divided into two main groups, lyophilic dispersions and lyophobic dispersions. Lyophilic dispersions are solutions in which the dispersed particle solvates, that is, absorbs the solvent. If the solvent is water, the process may be termed *hydration*. Proteins, gums and starches belong to the lyophilic colloids. Most of these substances cannot be obtained in crystalline form, although egg albumen and haemoglobin have been crystallized. Lyophobic dispersions are colloidal solutions in which the dispersed particle does not absorb the solvent. Most of the inorganic sols belong to this class.

A substance colloidal in character will not dialyse, that is, it will not pass through a semi-permeable membrane. Semi-permeable membranes are of the utmost variety, the most familiar example is a colloidion membrane. A fish bladder is another such membrane. Substances in true solution readily pass through such a membrane while a substance in colloidal solution will be held back. Dialysis is, therefore, a method by which true solutions may be separated from colloidal solutions.

Substances can be obtained in the colloidal state in two main ways; (1) by taking them in molecular solution, that is, a high degree of dispersion, and then partially coagulating them by special methods; or (2) by taking the substance from the coarse suspension end of the scale, and increasing by electrical or mechanical means their degree of dispersion, so that they come within the limits of size and act or are colloids. From the miller's standpoint, the important *colloid* is protein. Proteins are lyophilic colloids, they solvate and their power to absorb water and swell depends upon this process. The *pH* of the solution is the determining factor of the extent to which solvation will take place. Proteins are ampholytes, that is to say, they behave either as bases or acids depending upon the *pH* of the solvent.

The point at which the protein sends out equal numbers of anions and cations and does not migrate in either direction if placed in an electric field is called its iso-electric point. At this point the protein is least reactive, has its lowest swelling capacity, has minimum conductivity and is most easily precipitated out. The iso-electric point of proteins is determined by measuring the *pH* of the solution at which the protein shows least swelling, conductivity, and migration in the electric field, that is, electrophoresis. The iso-electric point varies greatly for the different proteins, thus for gliadin it is at *pH* 10.2, for edestin, 7.9, while for egg albumen it lies at *pH* 4.8.

Proteins are good adsorbents as are all substances in the colloidal state. Adsorption is a surface phenomenon and the degree of adsorption is determined by the surface area and the electric charge of the particles. The surface area of particles in colloidal solution is very great. The protective action which certain substances in the colloidal state will exert upon another substance in colloidal solution depends upon the adsorbility of the protecting colloid on the dispersed particles. The coagulation of substances in colloidal solution upon the addition of another colloidal solution depends largely upon mutual neutralization. In both these phenomena, the *pH* of the solution thus plays a major part.

Flour is essentially a mixture of starch, electrolytes, moisture and dried hydrogel known as gluten. On the power of this gluten to swell, that is, on its power of solvation, or in flour, hydration, depends its useful qualities. This swelling is partly under control and partly dependent on the original coagulation in the sap juices during the ripening stages of the wheat.

Coagulation can be brought about if the particles are negatively charged by the addition of hydrogen-ions which are positively charged; in other words, by the addition of acids. Final coagulation is probably electrical, but the coagulation of an emulsoid is essentially due to the de-hydration action. Colloidal solutions are termed suspensoids, if the particles are solids. If the particles are liquids, they are called emulsoids.

In the swelling of colloids, which takes place in the making of dough and the baking of bread, there are usually large energy changes; and heat, often in a considerable amount, will be given out. Also, gels which include hydrated doughs, often separate out into two phases, one of which is a liquid. This liquid is not, however, pure water or pure solvent, but a colloidal solution in both the colloidal and molecular degrees of dispersion. This reaction is the reverse of swelling, and the staling of bread is said to be due to this separation.

It is interesting, at this point, to mention the first account of commercial colloidal chemical reaction. In the Bible, when the Israelites were bidden to make bricks without straw, the Egyptians, without possibly knowing the colloidal chemical reason for the reaction of straw, knew from experience that the straw was necessary, if the bricks were to be strong and uniform in structure. It is possible that the colloid of the straw acted as a protective colloid to the colloid of the clay, and prevented coagulation, which would have caused the materials to become irregular, non-homogeneous and unreliable. This same method of reasoning has since been used in industrial developments in the ceramic field.

The definition and discussion of hydrogen-ion concentration and colloidal behavior of starch or gluten has been entered into for two reasons. *First,* because the adsorption of moisture by the flour or the gluten in the flour for the production of a proper loaf is dependent upon the hydrogen-ion concentration and upon the colloidal state of the resultant doughs. *Second,* because both of these conditions, that is, the hydrogen-ion concentration and the adsorption due to the colloidal nature of the ingredients are distinctly electrical, and very large forces are essential to the disturbing of the equilibrium of the dough or the loaf. Certainly the changes in the hydration of the dough or the loaf, are not due to the common conception of the effect of regain due to air conditioning, since it is almost impossible, except under the attack of very high temperature, applied for long periods of time, to remove more than a very small percentage of the hydrated solvent, and then only at the expense of changing the entire structure of the ingredients themselves. As already stated, even the staling of bread, usually considered a dehydration factor, has been proved by innumerable tests to involve only a very small loss of

moisture, and a very definite change in the chemical structure of the ingredients.

It has been proved that the variation in cohesent water contents of gluten extracted from different flours is due to the development of electric changes around the particles of the protein or to chemical inter-action between protein acid or alkali and water, and that the density and water content of a solid mass of moist gluten depends, to a certain extent, on the disappearance of the electric double layers surrounding each particle.

Fermentation

In the fermentation process, the colloidal nature of the yeast or the enzymes affected by the yeast is greatly affected by temperatures. Jago, in his comprehensive study of the technology of bread-making, has stated that success in the manufacture of bread (sound materials, of course, being a first requirement) like all other operations in which fermentation is important, is dependent upon a proper regulation of *temperature,* because extremes of temperature in either direction weaken the action of yeast. In order to insure a uniform dough, it is essential that temperatures be kept as nearly constant as possible, during the whole of the fermentation.

Good yeast works well at from 80 to 85 F and at these temperatures lactic and butyric fermentation proceed slowly, even in the presence of those organisms which induce these types of fermentation. Sometimes cold is most detrimental and may even produce a sour loaf. However, to return to the subject of fermentation, the expanding of the dough so that it may hold the water of hydration is due to the expansion of the colloidal gluten cells by means of the expansion of carbon-dioxide gas, which eventually is released or forced out by its undeveloped pressure, partly during the fermentation period, and partly during the baking period. This formation of gas to which the leavening of the bread is due, is a very interesting chemical reaction, and is due to the catalyzing effect of living organisms or yeast spores on the carbohydrates inherent in the flour itself. These living organisms so familiar in all chemical changes in organic chemistry, have the effect of decomposing the starches into sugars, that is, of inverting cane sugar eventually into glucose and from glucose into carbon-dioxide and alcohol.

As previously stated, the *pH* concentration of the yeast affects materially the amount of carbon-dioxide that is developed from the sugars in the starch, and from the additional sugars added in the doughs. The maximum is the same *pH* concentration that the gluten reacts best to, that is *pH*5. Pasteur has called this *the correlative phenomenon of vitalax* and it may be applied to that group of chemical changes which are related to the life or developments of certain minute microscopic organisms.

The term fermentation in its widest sense refers to the microbiological transformation of carbohydrates, proteins and fats into their simpler components. If this decomposition is brought about by chemical means, strong acids or alkali and heat are necessary. At the temperature and *pH* at which most fermentations proceed, the substrate (substance acted upon by the ferment or enzyme) is stable. Fermentation, when first discovered, was thought to be a microbiological action, but it has been shown that extracts of the organism were also capable of bringing about the decomposition of the substrate. Thus, alcoholic fermentation can be brought about either by living yeast cells, or by yeast extract free from any cells, or dead yeast cells.

Yeast is rich in enzymes. Diastase, the starch splitting enzyme, invertase, the enzyme which breaks down sucrose to its two component hexoses, glucose and fructose, and zymase, the enzyme which produces alcoholic fermentation of the hexoses are all present in yeast. In alcoholic fermentation the hexoses (glucose, fructose or maltose) are broken down to CO_2 and ethyl alcohol, C_2H_5OH, the theoretical yield being two molecules of ethyl alcohol and two molecules of CO_2 per molecule of hexose.

As stated, temperature is of great importance in influencing yeast activity. The temperature most favorable for activity as well as growth is from 77 to 95 F. At a temperature lower than 77 F, yeast growth proceeds, but slowly. At a temperature of approximately 50 F, the action of the yeast is arrested. However, the vitality is not destroyed, but only suspended, for at a higher temperature it again acquires the power of fermentation. Even freezing does not destroy yeast, unless the cells are injured. Above 95 F heat tends to weaken the action of yeast, until at 140 F the yeast is destroyed and it is at this temperature that the protein begins to coagulate. Of course, when dried, the cells can stand higher temperatures than when suffused with water. The whole theory of the formation of carbon-dioxide by the action of yeast on the various sugars in doughs is of extreme interest as paralleling to a great extent, the action of enzymes on the digestive system of the human body.

As affecting the value of air conditioning in the bakery, it is interesting to note that the loss during fermentation amounts to from 3 to 6 per cent and dough allowed to stand from 8 to 9 hours at a temperature of 85 to 90 F and then maintained at a constant temperature of 212 F for ten days, was found to have lost only 2½ per cent compared with the flour, and after the extreme temperatures of baking of from 450 to 500 F, the baked bread contained from 35 to 40 per cent of moisture.

Table 1 which is taken from Jago's Technology of Bread Making would indicate that the loss during the fermentation period is approximately the loss due to the evolvement of carbon-dioxide. The excess in weight lost over the amount of gas evolved is from 1 to 1.85 per cent. Therefore, very little escapes from the dough during fermentation, except the gas produced, the alcohol remaining in the dough, and these two weights, that is the carbon-dioxide and the alcohol approximate very closely the amount of sugar which has disappeared. A certain amount of soluble matter is produced by fermentation and this may be driven off. However, this is not likely to be affected by exterior conditions.

General Use of Air Conditioning

There is practically no mention in any of the articles on any investigations of bread-making of any definite effect of moisture content of the surrounding atmosphere on the quality of bread, whereas temperature and drafts are of continual recurrence in all of the technology on the subject. However, as has been stated, a definite condition of temperature and humidity is considered essential to proper machine manufacture of standard loaves of

TABLE 1—VARIOUS DATA OF DOUGHS

	1	2	3	4	5	6	7	8
Solids of doughs calculated from weights taken, per cent	57.44	57.38	57.00	57.30	57.30	57.30	57.15	57.30
Water of doughs calculated from weights taken, per cent	42.56	42.62	43.00	42.70	42.70	42.70	42.85	42.70
Solids determined on new-made dough, per cent	57.28	57.79	.....	.....	57.50	57.50	57.66	58.24
Water determined on new-made dough, per cent	42.72	42.21	.....	.....	42.50	42.50	42.34	41.76
Loss of dough in making, in grams	1.0	2.0	2.5	2.8	1.4	2.7	3.5	3.9
Dough taken for fermentation, in grams	292.0	294.0	297.3	297.7	296.1	297.7	296.9	299.0
Loss of weight during fermentation, grams	0.40	1.50	4.00	4.60	3.80	3.20	5.40	5.60
Volume of gas evolved at 64.4 F and 760 mm pressure, in cc	0.00	0.00	1,670	2,609	1,820	1,827	2,387	1,836
Weight of gas, CO_2, evolved in grams	0.00	0.00	3.09	4.71	3.37	3.38	4.42	3.39
Approximate weight of sugar required for production of gas, in grams	0.00	0.00	6.68	10.40	7.28	7.31	9.55	7.34
Approximate weight of alcohol produced, in grams	0.00	0.00	3.34	5.20	3.64	3.65	4.77	3.67
Weight of alcohol produced per 100 grams of dough, i. e., per cent	0.00	0.00	1.12	1.76	1.24	1.22	1.65	1.22
Loss of weight during fermentation, per cent	0.13	0.51	1.34	1.56	1.28	1.07	1.82	1.87
Sum of the two preceding quantities	0.13	0.51	2.46	3.32	2.52	2.29	3.47	3.09
Weight of sugar required per 100 grams of dough, i. e., per cent	0.00	0.00	2.24	3.53	2.48	2.45	3.21	2.45
Difference between the two preceding quantities	0.13	0.51	0.22	−0.21	0.04	−0.16	0.26	0.64
Soluble extract of the fermented dough, per cent	4.07	5.91	3.81	3.97	3.50	4.28	4.63	4.94
Subtract soluble matter of unfermented dough, per cent	3.29	3.33	3.29	3.29	3.89	3.92	3.28	3.91
	0.78	2.58	0.52	0.68	−0.39	0.36	1.35	1.03
Add sugar required for production of gas, per cent	0.00	0.00	2.24	3.53	2.48	2.45	3.21	2.45
Soluble matter produced during fermentation of dough, per cent	0.78	2.58	2.76	4.21	2.09	2.81	4.56	3.48
Ditto calculated on water-free solids of dough, per cent	1.35	4.41	4.88	7.58	3.76	4.97	8.21	6.12

bread. In Fig. 1 the conditions considered most favorable to the making of bread have been indicated. There is no doubt that the relative humidities in the various departments of the machine bakery are of definite importance, and have a definite effect on the flour, the flour itself being only slightly colloidal. The hydroscopic nature of a cellulose material is affected by a difference in relative humidity but not to anywhere near the extent ordinarily imagined. In fact, if the air-conditioning engineer were dependent upon the conditioning of the flour storage for the output of his product, he would find himself materially lacking in work, because probably in not one out of a thousand bakeries would he ever install air conditioning in the flour storage, and the slight difference in moisture content of the flour due to dry or moist conditions of storage space seldom exceeds 2 per cent as already pointed out. The probabilities are that air conditioning in the flour storage affects much more, the development of bacteria, such as molds, than it does the moisture of the flour.

From the flour storage to the fermentation room, there is no question that temperature is the determining factor, and this temperature is maintained solely with the idea of regulating the rate of fermentation. In other words, as fermentation should not proceed while the ingredients entering into the dough are being homogenized, means are required to offset the heat of the mixing processes in order that homogenization should proceed to its maximum point before the yeast becomes active.

During the fermentation period, when the doughs are allowed to stand in troughs in a specially constructed room (see Fig. 2), a temperature of about 80 F, which is satisfactory to the fermentation process, should un-

FIG. 2—DOUGH ROOM OF BAKERY SHOWING DOUGH TROUGHS AND AIR DISTRIBUTION PIPING

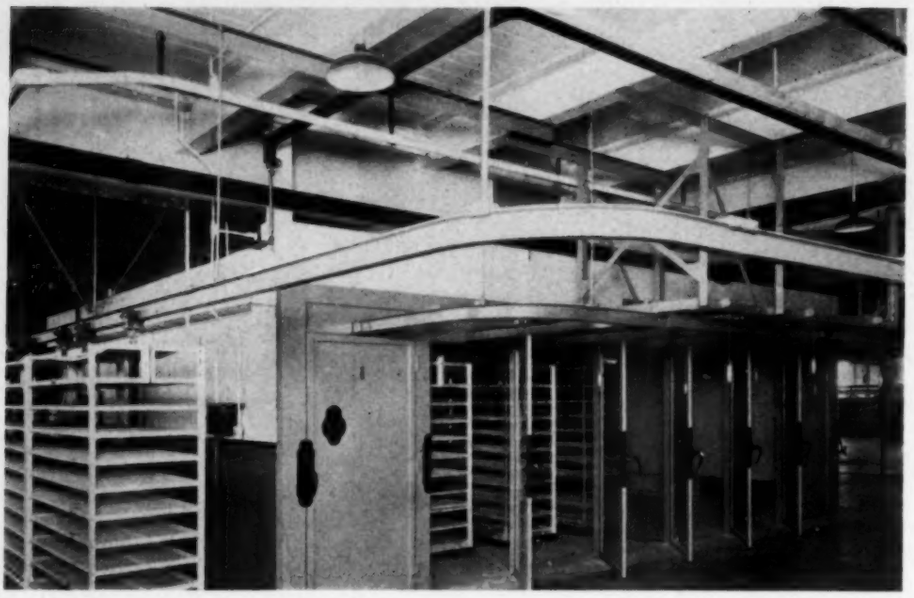


FIG. 3—FINAL PROOFER SHOWING RACKS FOR HOLDING BREAD SUPPORTED ON OVERHEAD TROLLEYS

doubtedly be maintained and maintained at a constant point during the 3 to 5-hr. period of fermentation.

There is no doubt that the passage of air over the exposed surface of the dough has a tendency to create a crust and it may possibly be that this crust is due to a difference in potential between the air passing over the ionized particles and the potential of the ionized air, and that the moisture content of the air required with the method of introducing this air for the maintenance of a definite temperature must be accomplished at such a high relative humidity that no static discharge is possible. This, to a certain extent, has been proved by one of the large bread manufacturers, for with a temperature of 80 F maintained in practically still air a much lower relative humidity than the 70 per cent usually called for by the air conditioning engineer has given satisfactory results. It is true that a certain amount of moisture is essential even under these still conditions, but very much less in quantity than has been regarded essential during the so-called air conditioning period of bakery development.

It is questionable whether the method of maintaining the desired temperature by direct radiation or by so-called bunker coils does not contain elements just as objectionable as the slight crusting which may occur due to the introduction of large quantities of air of the right condition. Furthermore, in the fermentation room where relative humidities of from 70 to 75 per cent are essential in order to prevent crusting, uniform conditions in the room are readily maintained and where all the air is handled through one central apparatus, the introduction of make-up air to take the place of air which has leaked outside is readily accomplished with modern air-conditioning equipment.

If this air could be introduced along the floor and under the troughs so that no air at high velocity impinged on the dough, probably lower relative humidities could be utilized than are now employed, with eminently satisfactory results. The crusting of dough is certainly to be avoided as it prevents an even release of carbon-dioxide and allows the formation of bubbles in the fermenting dough with consequent coagulation and unequal fermentation.

It has been stated that yeast is a living organism and is very greatly affected by change in its environment. Therefore, great care has always been essential in the handling of doughs from the time fermentation starts, and as doughs after fermentation are rather roughly handled in the make-up department, a certain amount of crusting is necessary in order to build up the gluten envelopes before entering into new processes or new fermentations. Therefore, the dry-proofing or rest period after dividing, scaling and rounding has never been one of the departments in which the air conditioning engineer has had any particular interest, as temperature alone was considered of importance in this particular department, but probably the same coagulation which takes place in the fermentation room itself occurs, although to a minor extent, in the doughs entering the rest period and this could be avoided if uniform conditions for the prevention of unequal crust hardness were utilized.

However, after the dry-proofing, when the rounded doughs in their respective containers are subjected to final proofing, air conditioning is in its *happy hunting grounds*. In other words, practically all American machine-made bread today is subjected to a final proofing in a special box in which a definite condition of temperature and humidity has been maintained with entirely satisfactory results. An illustration of a modern proof box is shown in Fig. 3.

It is almost a universal practice to maintain a temperature of 95 F during the final proofing period. This temperature is consistent with all of the technology of breadmaking, in that it corresponds to the maximum development or maximum satisfactory development of the yeast. The 70 per cent relative humidity, which it is customary to maintain in this final proofing, cannot possibly have any effect except on the exposed surface of the dough in the pan. Whether the fact that the relative humidity required for proper final proofing is the same as the relative humidity required in the fermentation room, under conditions previously mentioned, is due to an electrical phenomenon or not is a matter that should be thoroughly investigated. Certainly, the maintaining of a definite

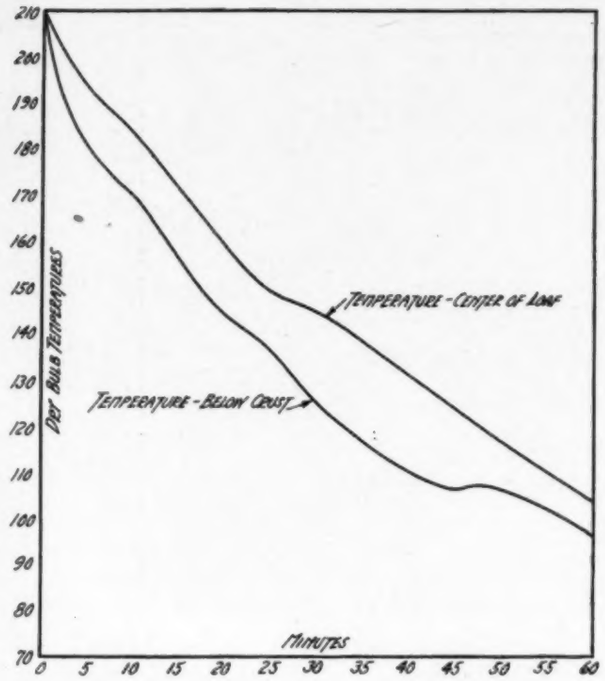


FIG. 4—COOLING CURVES FOR 1½ LB. VITAMINE BREAD—ROOM TEMPERATURE 79 F

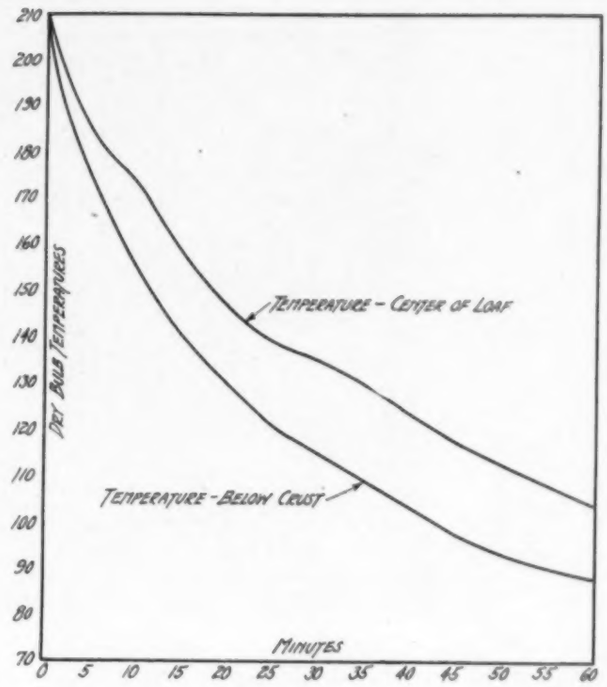


FIG. 5—COOLING CURVES FOR 1½ LB. SOFT BUN BREAD—ROOM TEMPERATURE 80 F

condition in the final proofer allows all of the pans to develop in the same length of time, and consequently permits of the removal of the fully developed dough at a very definite period, which corresponds with the time schedule of the balance of the bakery.

It is very doubtful whether the percentage of moisture in the air has any particular effect on the ultimate weight of the baked loaf. Certainly, the final proofer, when the conditions are recorded on recording instruments, is an efficient check-up for the manufacture of the loaf. However, it is the writer's opinion that the introduction of moisture-laden air at a definite temperature into the final proofer is much more a temperature problem than it is a moisture problem, unless the high percentage of moisture affects the hydrogen-ion concentration.

From the final proofer, the pans are introduced into the oven, and in this particular case there is no doubt that the high temperature of the oven is for the coagulation or caramelization or sterilization of the baked loaf, and the introduction of steam into the oven is certainly done for no other purpose than to assist in this caramelization, the moisture and temperature of the steam caramelizing the sugars on the surface.

The loss of weight which occurs in the oven is principally due to the moisture driven off from the surface of the loaf and from the volatiles which are released in the oven, and such slight amounts of carbon-dioxide as remain after the final proofing and from the alcohol

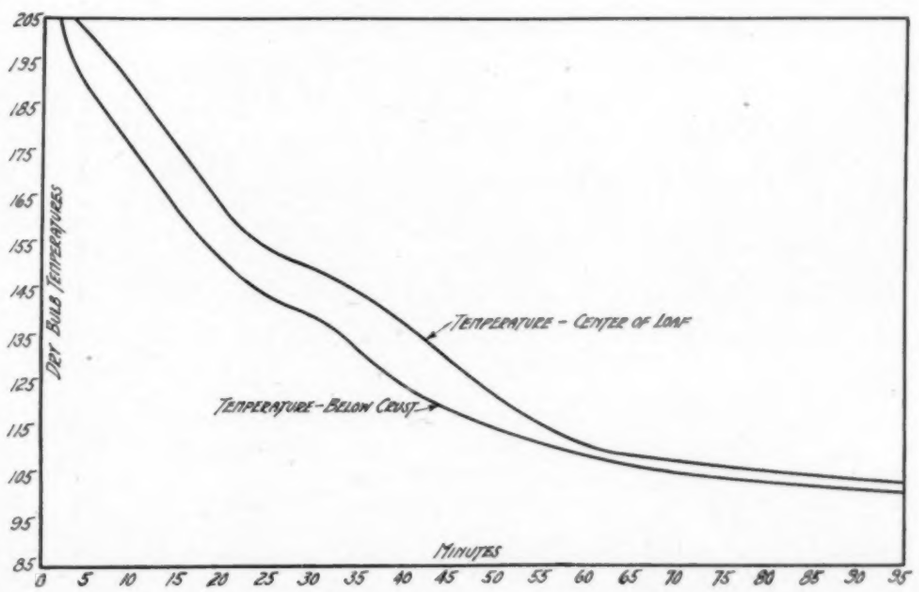


FIG. 6—COOLING CURVES FOR BAKERS' BREAD

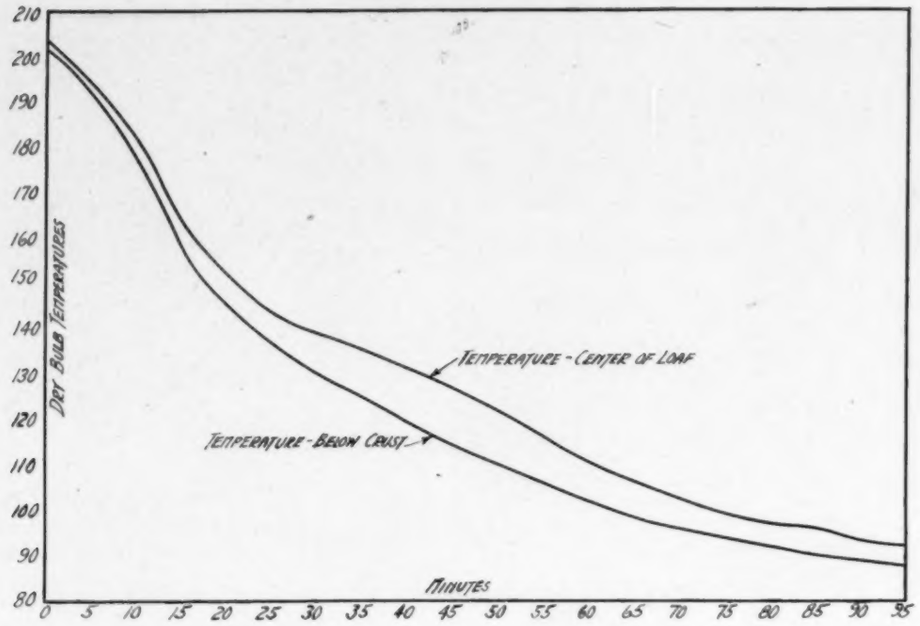


FIG. 7 — COOLING CURVES FOR BAKERS' BREAD

which is a by-product of the fermentation process, the alcohol remaining in the loaf until driven off by the temperature of the oven.

When the bread which is finally baked and is encased in a practically impervious crust is removed from the oven at a temperature of about 200 F, cooling proceeds very rapidly as shown in Figs. 4, 5, 6, 7 and 8. Figs. 9 and 10 show views of bread coolers of two large western bakeries. The amount of moisture lost during the cooling process is slight, probably not over 0.5 per cent, which percentage would correspond to the cooling effect due to evaporation of the moisture and volatiles involved in the cooling process.

There is considerable controversy as to the reason for the necessity of cooling a loaf to a definite temperature, usually below 100 F before hermetically sealing it in some exterior wrapping. It is the opinion of the writer that temperature is of considerably more importance than humidity and possibly the temperature has a great deal to do with the development or formation of mold growth and the keeping quality of the bread. In other words, as all ferments are less active at low temperatures, and as bacteria are in the nature of true ferments, the cooler the loaf, the more unlikely the formation of any deleterious growth.

As stated earlier in this paper, even the staling of bread which was assumed to be due to a loss in moisture has been proved to be a chemical change and not a dehydration process. Therefore, the suggested vacuum method of removing heat and moisture from baked loaves does

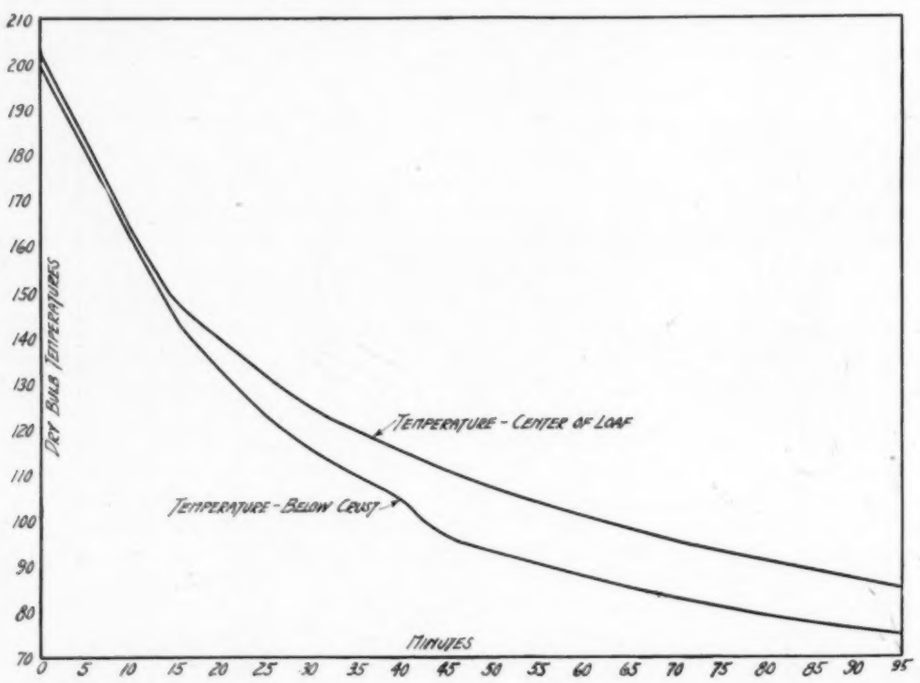


FIG. 8 — COOLING CURVES FOR BAKERS' BREAD

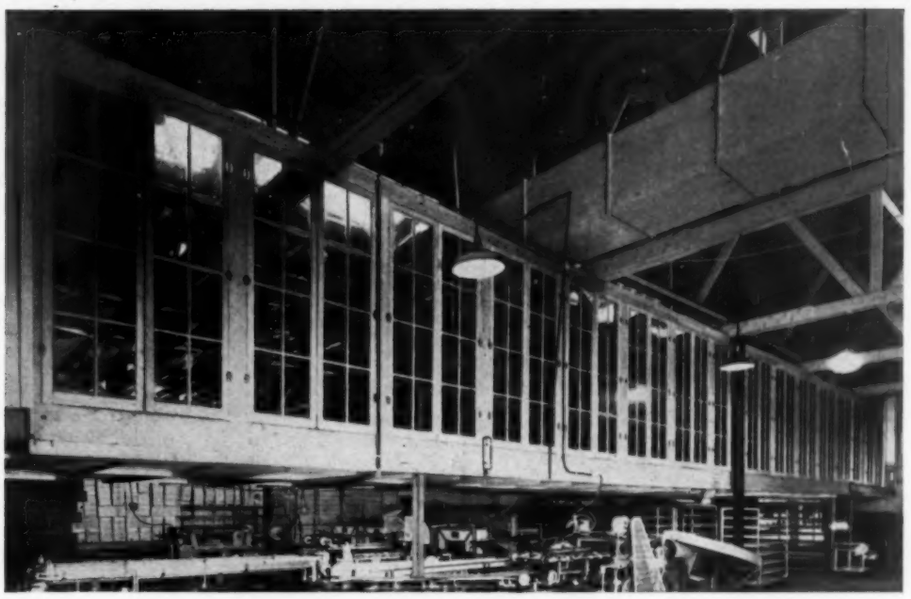


FIG. 9—BREAD COOLER IN A WESTERN BAKERY

not seem absolutely logical when the chemical changes which create the stale or inferior loaf are taken into consideration.

Conclusions

The supreme importance of the hydrogen-ion concentration of the various ingredients that enter into the making of bread; the relationship between the hydrogen-ion concentration and the colloidal nature of the principal ingredients of bread, which colloidal condition is itself electrical; the possible hydrogen-ion concentration in air at 70 per cent relative humidity which has been over a course of years, found most effective in the present method of conditioning doughs and bread, through the bakery—these interesting problems should be investigated further with respect to the use of air conditioning as such, in the making and baking of bread. An investigation is suggested of the strangely familiar development of bread structure, a colloidal state; and also of the maximum temperature of efficient fermentation affecting the development of all articles of food with the necessity of the introduction of food into the digestive system in a colloidal state, and the most efficient temperature of life of approximately 98 F. Whether an electrical explanation of the various phenomena entering into the development of food and its digestive qualities and the hydrogen-ion concentration of the blood at different relative humidities will give rise to new concepts of life and health are still to be developed in the physical laboratory.

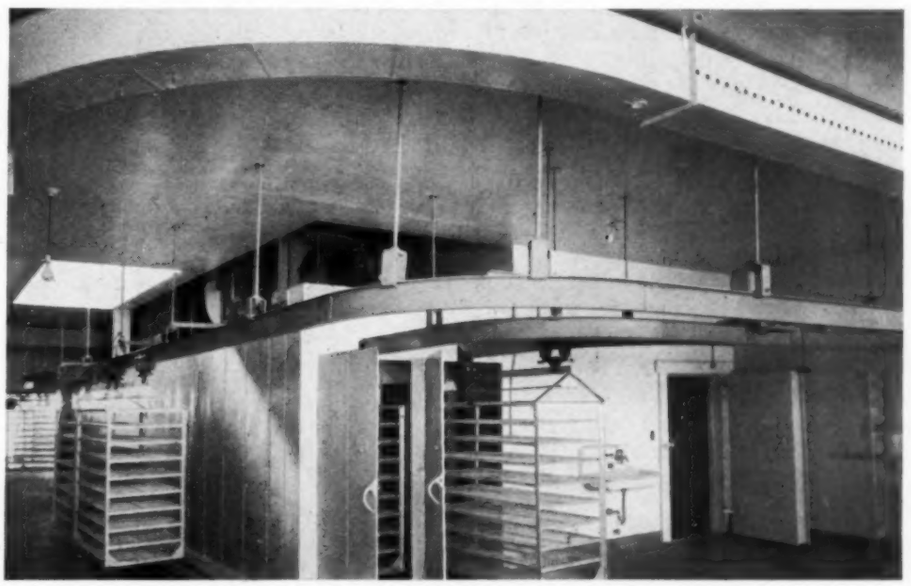


FIG. 10—BREAD COOLER WITH AIR CONDITIONING UNIT ON TOP SHOWING BREAD RACKS SUPPORTED ON MONO-RAIL TRACK

Heating Effect of Radiators

By R. V. Frost[1], Norristown, Pa.
MEMBER

IN A PAPER ON enclosed radiation[2] presented before the Society at Boston in January, 1925, the writer submitted data on some tests conducted in 1914, showing that by merely placing a straight box enclosure about a cast-iron radiator[3] the average temperature at the breathing line of the room could be increased while at the same time the condensation from the radiator decreased. This, it is believed, was the first presentation of what is now known as *radiator heating effect*. The generally accepted explanation of this phenomenon is that the cabinet radiator distributes the heat at a lower level than does the direct radiator, but in tests of cabinet-enclosed, fin-type radiation conducted during the summer of 1930, the writer obtained data that give support to another explanation. This explanation, however, is not new, for the writer first suggested it in articles published in 1926, but he had no way at that time of definitely proving the theory involved.

These tests were conducted in a calorimeter room which, although similar in its general details to many other radiator test rooms in the country, differs from most of them in that the cooling effect is obtained by a direct method. Some experimenters have described it as a water-cooled wall method. It provides the following three methods of cooling:

1. Direct cooling by a sheet of cold water flowing over the outer wall surface, shown in the elevation, Fig. 1.
2. Cooling by air over the outer wall surface.
3. A combination of (1) and (2) with added cooling effect by evaporation.

The choice of the method depends upon the weather conditions and the conditions under which it is desired to test. In winter, air is used and in summer, water or air and water combined.

Description of Test Rooms

The general layout and dimensions of the rooms are shown by the floor diagram, Fig. 1. The outer walls and the floor and ceiling of the calorimeter room are insulated with 12 in. of cork, thus making possible the maintenance of extremely uniform conditions. This uniformity has been demonstrated, when, with a wide variation in the outside temperature, the temperature within the test room did not vary one-half degree over a 24-hour period.

The calorimeter room contains two separate test rooms of equal dimensions which are neither communicating nor have they a common wall except through a connecting passage. The cooling surface walls are of sheet metal painted with light yellow semi-gloss oil paint. They comprise walls on two sides, or one-half the total wall surface of each test room and each wall contains one double-hung window fitted with metal weatherstrips or two windows per room.

When air is used for cooling, the velocity over the wall surface is equivalent to a 12-mile wind while the wind pressure, when infiltration is considered, can be made equivalent to the pressure of a 40-mile wind. When water is used for cooling, the water for each room is drawn from the same cooling tank but passes through separate meters, valves and pipes so that it is possible accurately to balance the cooling effect on the two rooms. This arrangement has made it possible to obtain exact determinations of heating effect. It was found that a variation of one-half degree in room temperatures upset the conditions quite seriously and it was therefore necessary to secure a very exact balance between the two rooms to be certain of the results.

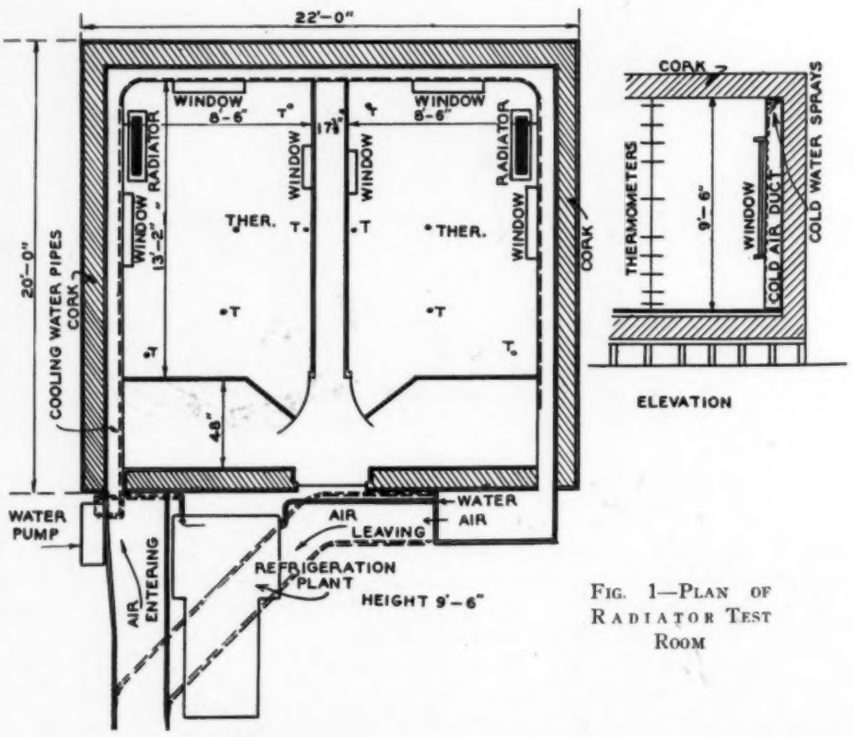


FIG. 1—PLAN OF RADIATOR TEST ROOM

[1] President, Frost Research Laboratory.

[2] *Some Facts About Enclosed Radiation*, by R. V. Frost (A. S. H. V. E. TRANSACTIONS, Vol. 31, 1925).

[3] The word *radiator* is used in the commercial sense and not in the scientific sense in this paper.

Presented at the 37th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Pittsburgh, Pa., January, 1931.

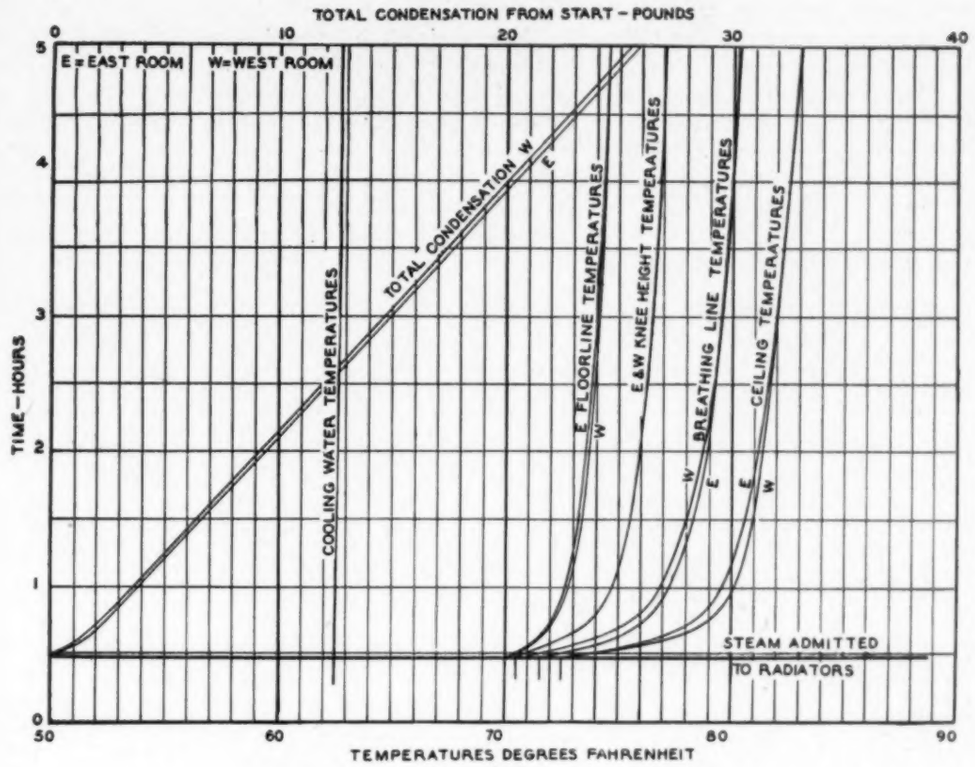


FIG. 2 — COMPARISON OF RADIATOR TEST ROOMS WITH IDENTICAL RADIATORS

Procedure for Making Tests

The procedure in these tests was first to balance the two rooms by testing two radiators of identical size, one in each room, and adjusting the cooling water flow over the walls of the two rooms until the temperature conditions in the two rooms were exactly the same for the same rate of condensation. Such a balanced condition is shown in Fig. 2.

Radiator *A* was then placed in one room and radiator *B* in the other. The locations of the radiators are shown on the plan of the test room (Fig. 1) and it will be noted that they are in relatively the same location in each room. After the radiators had each been tested in one room they were interchanged and the tests repeated. The results of these tests are shown on Figs. 3 and 4. Both room temperatures and condensation

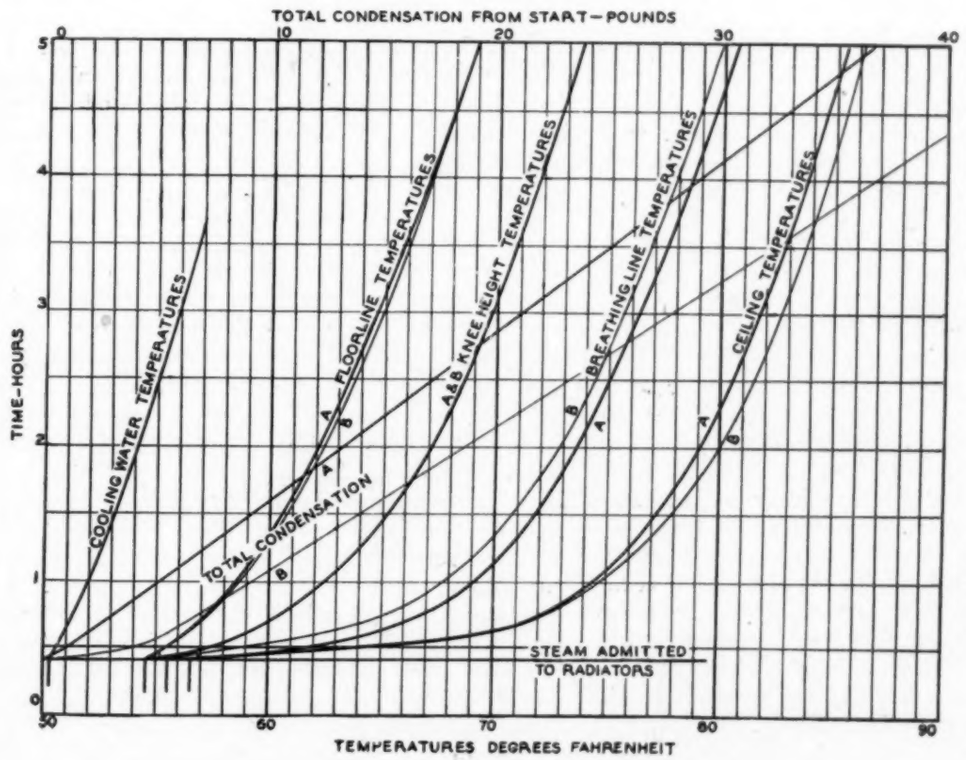


FIG. 3 — COMPARISON BETWEEN FIN-TYPE (*A*) AND CAST-IRON (*B*) RADIATORS (TEST 1)

are shown on these charts. The left ordinate represents time, the lower abscissa is room temperature, and the top abscissa, condensation.

The condensation as plotted represents total condensation from the start of the test. Four temperature lines are plotted, namely, average temperature of the room on the levels of 3 in. above floor, 20 in. above floor, 60 in. above floor and 3 in. below ceiling. In addition to these, temperatures at 10 in., 30 in., 40 in., 80 in., 90 in. and 100 in. were also recorded and are noted that there is a certain definite relationship between the four levels plotted and that after the first quick rise in temperature the lines flatten out to a slightly curved gradual increase that becomes less curved as the temperatures approach a higher level. In other words, the temperature lines take an elliptic shape that eventually leads into a vertical line as the heat exchange becomes perfectly balanced.

It should be noted that the ceiling temperature for Radiator *A* was much lower than for Radiator *B*, but

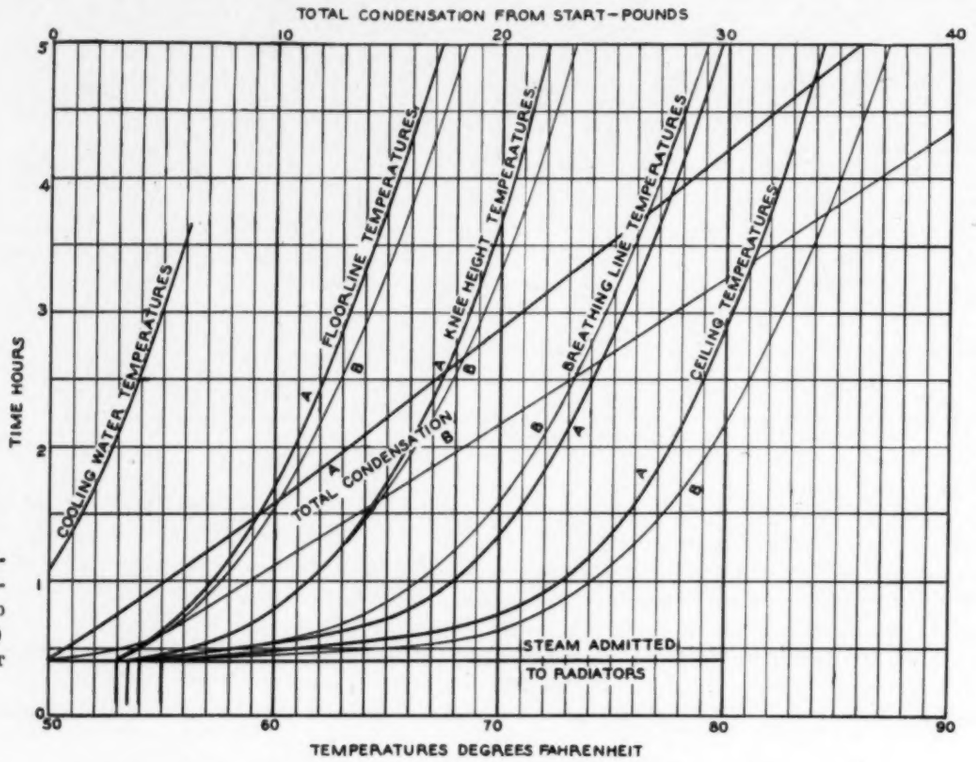


FIG. 4 — COMPARISON BETWEEN FIN-TYPE (*A*) AND CAST-IRON (*B*) RADIATORS (TEST 2)

indicated on Fig. 6. Condensation and room temperature for both rooms are plotted on the same chart to give a graphic comparison.

It will be noted that there is some variation between Figs. 3 and 4, although the two rooms had been previously balanced very closely. This variation was due largely to the wide calibration of the thermometers. To compensate for this variation, Fig. 5 was constructed and this is regarded as the official chart of the test. It is a composite, average chart of Figs. 3 and 4.

One objective was to have the floor line and knee height temperatures of the two rooms coincide. This was accomplished as closely as possible by proper selection of the radiators used for comparison. By having this condition, it was possible to assume that the temperature conditions surrounding the two radiators were identical and so to offset the possibility of the claim being made that the test conditions were unequal.

In the study of the curves, consider first the temperature lines. The short vertical lines at about 55 F at the bottom of Figs. 3, 4 and 5 represent the temperatures in the rooms before the start of test. Steam was then admitted to the two radiators simultaneously as indicated by the horizontal lines, and the temperatures in the two rooms began to rise immediately. It should be that the breathing line temperature for Radiator *A* was higher than for Radiator *B*. In other words, the difference between the ceiling temperature and the breathing line temperature for one radiator is much less than for the other.

Analysis of Results

For the purpose of comparison, the cooling water temperature is shown in its relationship to the room temperatures. It bears a very close relationship, at least in appearance, to floor line temperature.

The condensation lines are very slightly curved as is to be expected due to the fall in condensation with a rising room temperature. When a balanced condition is reached without a rise in temperature then the condensation lines will become straight lines. An interesting observation is to be noted in comparing the lower sections of these condensation lines. One represents the condensation from a fin-type radiator having but a proportionately small weight, and the other is from a cast-iron radiator. The effect of the additional weight in the cast-iron radiator is shown by the immediate increase in condensation from this radiator. It should be noted that after the cast-iron radiator is heated up the condensation line begins to straighten out.

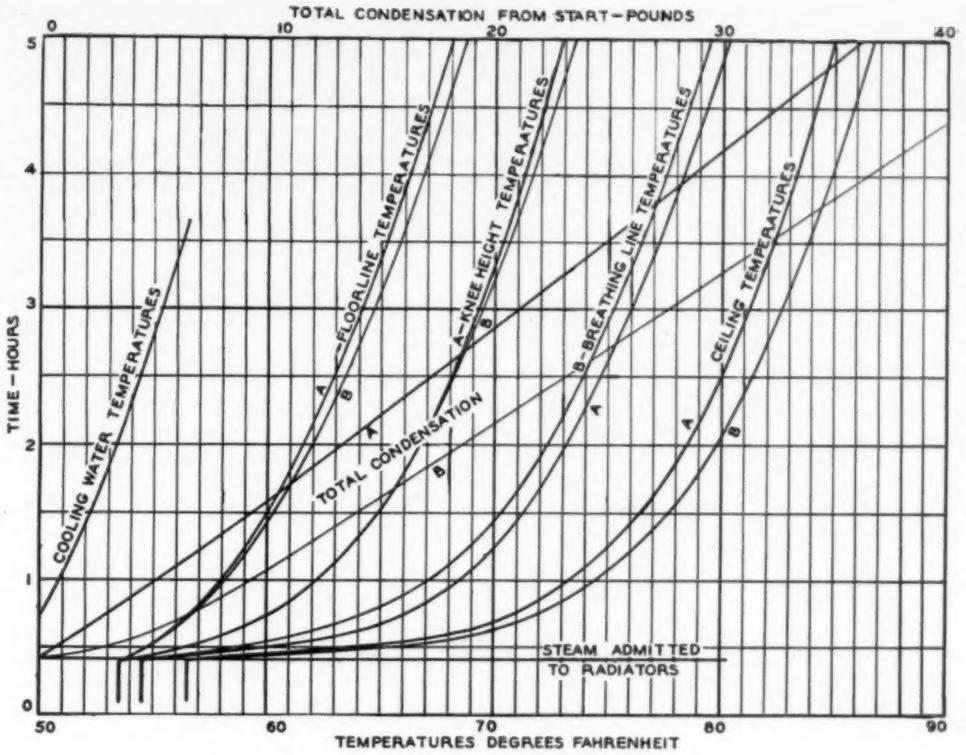


FIG. 5 — COMPARISON BETWEEN FIN-TYPE (*A*) AND CAST-IRON (*B*) RADIATORS (COMPOSITE OF TEST 1 AND TEST 2)

The important feature about the condensation from the two radiators is shown in the gradual spreading of the two condensation lines. It is apparent that the fin radiator equipped with a cabinet heats the zone from the floor to the breathing line with a much lower hourly rate of condensation. On this chart (Fig. 5) a graphic explanation of the entire phenomenon of heating effect is given. Two radiators used for heating two rooms of equal cooling effect, start with the same room temperature at the beginning of the tests, and build up the temperatures of the two rooms over a period of several hours at precisely the same rate in the zone occupied by the radiators, that is from floor to knee height, each radiator operating under the same temperature conditions, and yet the one with the cabinet condenses less steam consistently throughout the period.

It would appear that the explanation lies in the lower temperature at the ceiling, but the curves of Fig. 6 might indicate otherwise. These curves are for the average temperatures from floor to ceiling for each radiator. One set of curves is plotted on the basis of a temperature of 70 F at the knee height level and the second at a temperature of 70 F at breathing line level. The averages for the curves are tabulated on Fig. 6. It will be observed that for a temperature of 70 F at the knee height level, the average temperatures for the full height of the two rooms are but 0.1 deg apart and likewise when the averages are taken for 70 F at the breathing line the difference is 0.1 deg. It is true that the averages for the zone from floor to breathing line are higher for the cabinet radiator than for the exposed cast-iron radiator but with each room raised to the same average temperature over the entire room it is apparent that each room has absorbed virtually the same amount of heat from each radiator. Therefore, the cause for the difference in condensation rate must lie in some other explanation.

For the usual type of room construction and with a 20-deg difference between the wall temperature and the average room temperature, the hourly rate of condensation for this particular type of cabinet was about 20 per cent less than the hourly rate from the exposed radiator. But if a shield is placed in back of the exposed radiator, the rate of condensation from this radiator now decreases so that the percentage in favor of the cabinet drops to about 14 per cent.

Explanation of Result Obtained

This indicates that the cabinet prevents the dissipation of heat by radiation, a large part of which passes out through the windows and walls of the room. By placing a shield between the radiator and wall a portion of the radiation loss is prevented and if the room were completely insulated to prevent the loss of all radiant heat so that the heat from the radiator were used only to heat the air in the room the heating effect of the exposed radiator would then be equal to that of the cabinet radiator.

Rooms are built with considerable glass surface and as the ratio of glass to exposed wall surface in recently constructed buildings is on the increase rather than decrease, an increasing radiation loss from this source is probable. Therefore, in the design of a radiator it is well, if fuel economy is a factor, to give consideration to the loss of radiant heat and to design the radiator to give the highest heating-effect ratio. In fact, it is evident that heating effect, in comparing the value of radiators, will become of increasing importance.

Returning to a discussion of the test room, it is apparent that the wall temperature is indicated by the temperature of the water flowing over it, since the wall material is sheet steel, painted with a yellow gloss oil paint. This material having a high conduc-

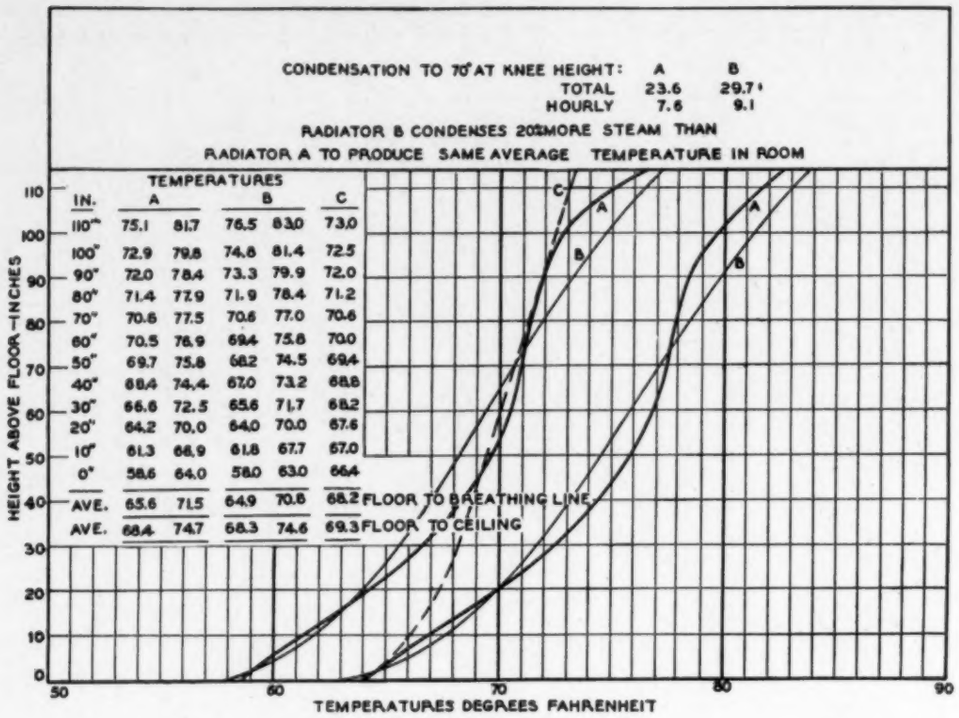


Fig. 6—Test Room Temperatures—Floor to Ceiling

tivity, transmits the heat to the water with a minimum resistance, so that although there is some loss, it is negligible and cannot be detected in the water temperature.

It has been claimed that this wall construction is not comparable to normal heating conditions. The only difference between this wall construction and the usual wall type is that this wall responds to temperature changes quicker than would a standard exterior wall, and that under the method of testing used, a condition was duplicated in a few hours that required days to work out in the usual problem of heating. Fig. 7 shows the conditions for normal heat transmission compared to the test room used. In zero weather the inside wall temperature is approximately 58 F, the temperature gradient being as shown on the left. To obtain a wall temperature of 58 F in this test room, the cooling water was maintained at 58 F, but as far as the surface with which the air of the room was in contact or which received the radiant waves of heat, there was no difference between the standard wall and this test room wall, provided both walls were painted surfaces of the same color. The wall in these test rooms will not transmit heat any more rapidly under given inside wall and air temperature conditions than will the standard wall at zero outside. In fact, these tests have shown that for the total area of exposed wall surface in the test rooms the heat demand is about equivalent to that of the same area of standard wall in zero weather.

There are many kinds of wall construction, all with different rates of heat transmission and a radiator test room built up of thick walls similar to those of a building, could not be used to study the effect of different rates of heat transmission. The metal, water-cooled walls, on the other hand, have the advantage of flexibility, and can by proper regulation of the cooling water temperature be made to duplicate almost any type of wall construction. This is illustrated in Fig. 7 in which a standard type of building wall is shown on the left, with the temperature gradient from 70 F inside temperature to zero outside, shown dotted. On the right is shown the metal, water-cooled wall of the test room. As the metal wall in contact with the cooling water assumes the temperature of the cooling water within a small fraction of a degree, it is apparent that cooling water at 58 F will duplicate zero degrees outside in the particular wall shown on the left. Other walls can be similarly simulated; for example, 50 F cooling water

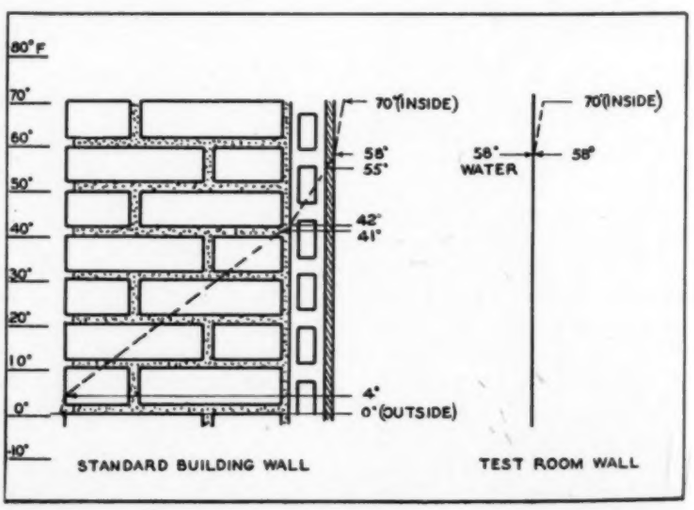


Fig. 7—Temperature Gradients Through Standard Wall and Test Room Wall

would correspond to an 8-in. brick wall, unfinished inside, or a 16-in. stone wall (sandstone or limestone), unfinished inside.

The test rooms were not built so much to comply with standard test conditions as to provide a means of studying heating effect. The tests reviewed in this paper were among the first conducted specifically in this laboratory for that purpose, and the results have been sufficiently encouraging to warrant the belief that it will be possible to gather further data on the subject of heating effect that will clear up many other questions on the matter of radiator heating.

Conclusions

In arriving at conclusions regarding the value of heating effect, the effect due to radiation loss should not be confused with the improved air distribution in the room. The tests demonstrated that not only does the cabinet over the radiator prevent the loss of a large percentage of radiant heat, but that it also distributes the heat at a lower level.

The two factors cannot be determined by the same tests. These tests were intended to prove that there is a loss of radiant heat and to determine the percentage of that loss. They have also shown that there is a better distribution of the heat when a cabinet is used, but the value that can be placed upon that better distribution, this study does not indicate.

It is permissible to assume, however, from the data here developed, that a cabinet over a radiator can save at least 20 per cent by better utilization of radiant heat, and an additional percentage of a definite value, by better distribution of heat in the living zone. To determine the exact percentage of heat saving due to better distribution requires a different method of test than the one described in this paper and this percentage is dependent upon many factors in addition to the cabinet.

It would be very desirable to combine these two factors in order to determine the full value of heating effect, for it is apparent that many of the new types of radiators cannot be installed on the old condensing basis of rating. One such radiator by the mere diffusion of heat at a low level has been found to heat the zone from the floor to 3 ft above the floor to the same temperature as another that condenses 60 per cent more steam.

With this type of radiator the temperature at the breathing line will be lower than with another but to a person sitting in the room the degree of comfort with the first is higher than with the second for the reason that the major portion of the body is in a higher temperature, as indicated by line *C*, Fig. 6. If this radiator is installed on the basis of its condensing capacity, overheating results. Therefore, the condensing capacity of this radiator is not an accurate index of its useful heating capacity.

The desirability of a new method of rating radiation is apparent. For years the assumption has been accepted that the relative humidity is an index of heating comfort. Is it not possible that uniformity of temperature, not on a time scale, but uniformity on a scale of vertical height, is an equally important index of comfort? Certainly if one's integument must adjust itself to changes of temperature of from 5 to 10 deg every time a change is made from a standing to a sitting position, one's constitution will be subjected to a severe strain.

The problem of radiator heating does not, in the writer's opinion, involve merely the emission of heat. The matter of heating effect is equally as important.

Radiators and Convectors

Direct radiators, direct-indirect or exposed heaters emit heat by radiation and conduction whereas concealed built-in heaters, cabinet heaters or indirect heaters emit heat mainly by the process of convection. An exposed cast-iron radiator emits from 10 per cent to almost 30 per cent of its heat by radiation, according to determinations made at the Research Laboratory of the American Society of Heating and Ventilating Engineers. The balance or major portion of its emission is, of course, by conduction to the air in contact with the heated surfaces. Thereupon the heated air, through convection, sets up a circulation which tends to distribute the heat more or less uniformly in accordance with the manner in which the convection currents are utilized.

When a cast-iron radiator or one of the newer non-radiating heaters provided with extended conducting surfaces is enclosed within a wall or cabinet, it emits practically no heat by radiation, but functions by conduction and convection. Hence the term radiator or radiation applied to such heaters is distinctly a misnomer, which should not be perpetuated. And it should be equally emphasized that air is heated by conduction in contact with a heated surface, while convection is that phenomenon by which heat is distributed within a fluid, liquid or gas by movement of the fluid, liquid or gas.

In the past the unit of measure recognized in computing heat emission of radiators was the square foot of actual radiating surface. The use of this unit is being discarded rapidly, however, for the reason that heat emission depends upon the design of the heater as well as upon its surface area. The engineer is interested primarily in the amount of heat emitted by, rather than the amount of surface in, a heat-transferring agent. As a result, heaters are now rated on the heat given off either in Btu per hour or in equivalent square feet, based on 240 Btu per hour, and there is a growing demand for a new measure which will express also the room-comfort effect of the heater.

The purpose of supplying heat to a room is not alone to increase the temperature of the air in the building, but also to maintain a condition of comfort for the occupants. In this connection it cannot be denied that comfort-feeling for human beings in winter calls for the delivery of warmth to the lower part of the room or to the zone of occupancy, instead of for overheating the parts near the ceiling. Recognition of this principle has led to considerable study and speculation on economical application or distribution of heat in domestic heating.

Utilization of Hot Springs for Heating in Iceland

By Ben Gröndal, Reykjavik, Iceland
NON-MEMBER

Iceland is an island under the sovereignty of Denmark, located in the North Atlantic about 500 miles northeast of Scotland and 150 miles southeast of Greenland. The present population is about 95,000. The island has a length of 298 miles and a breadth of 194 miles, the area being about 40,000 square miles, of which less than half is available for farming and pasturage. The south shores are sandy lowlands, unbroken by bays or harbors, while the other coasts consist of precipitous cliffs, indented by numerous fiords. The harbors for shipping are on the southwest shores.

About one-eighth of the land is glacier hidden. Glacial moraines and lava streams have formed numerous depressions, wherein have gathered many lakes. The surface in general consists of a series of rough plateaus, formed of lava and other eruptive matter.

Its main area is barely outside of the Polar Zone, as the Arctic Circle intersects the most northerly points of the island. The south and west coasts are washed by the gulf stream and the north coast by an Arctic current which frequently brings with it a quantity of drift ice which has a considerable effect upon the climate of the island. The sub-arctic and oceanic location makes the climate harsh rather than extreme. While the average winter temperatures of the entire coast line vary slightly from 32 F, the summer averages of the north and east shores range between 43 and 44 F, as compared with 48 to 50 F on the south and west coasts.

Hot springs are numerous throughout several parts of the island, and in the so-called geyser region, about 30 miles northwest of Hekla, there are more than 100 in a small area. The most widely known of them is Great Geyser, which is 60 ft in diameter and has an intermittent period of discharge varying from 6 to 30 hours. It spouts water to a height of 150 ft or more, at temperatures varying from 170 to 190 F. One geyser was found to have a temperature of 262 F at its bottom—possibly the hottest spring in the world.

ICELAND is one of the largest volcanic countries of Europe. Old and extinct craters are to be found in many parts of the country, while there are several big volcanoes, some of which, such as Hekla, were active until only a few years ago. As a rule, the craters are surrounded by extensive stretches of lava. Most of them antedate Icelandic history.

In practically all parts of the country there are warm or hot springs, or outlets emitting steam. Until recently little has been done to utilize this gigantic store of natural heat which, if properly used, could render Iceland independent of all importations of fuel. Not until about four years ago did the people of the country begin to realize the advantage with which they were thus favored, as there is nothing comparable to be found elsewhere in northern countries. A number of farmsteads and school buildings, and a sanatorium in the North, have now been heated by water from the hot springs, or by subterranean steam. The water from most of the hot springs is alkaline and therefore does not corrode the pipes. On the other hand, the steam often contains a certain amount of sulphur compounds which form sulphurous and sulphuric acids and which corrode the pipe.

FIG. 1—WASH SPRINGS

Presented at the 37th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Pittsburgh, Pa., January, 1931.

When this subterranean heat was first utilized, the question arose as to whether it would be possible to meet the demand for heat where it was greatest, namely, in Reykjavik, the capital. The town is situated on the southern coast of Faxafloi about 50 miles from Reykjanes, where earthquakes are a common occurrence. Reykjavik has a population of about 27,000, but covers

FIG. 2—A BORE HOLE SPOUTING

a comparatively large area, most of the houses being detached and consisting of two stories and a basement.

The older houses are of frame construction, the walls being filled with sawdust or wood-shavings and covered on the outside with tarred felt and corrugated iron. These houses are fairly well insulated, but they are inflammable and lack durability. The construction of frame houses, however, has now been forbidden except by special permission. All buildings now erected are of concrete, the floors being reinforced with iron and the exterior walls lined on the inside with expanded cork. Modern buildings are invarably heated with hot water systems, and this is also a very common method of heating the older houses.

Electric current for power and light is obtained from a plant on the Ellidaar River at a distance of 3.7 miles from the town. This generating plant is now becoming insufficient, and a new one of 10,000 hp is contemplated on the Sog River at a distance of 31 miles from the town. The water supply for the town is obtained from cold springs at a distance of about 6.2 miles. Reykjavik has its own gas works and most of the main streets are paved with tarmac.

Investigation Authorized

Two years ago the *Icelandic Engineering Association* suggested the desirability of heating the buildings of Reykjavik by a system utilizing the subterranean heat. This idea was favorably received by the municipality and funds were appropriated for the purpose of an investigation to ascertain the feasibility of the undertaking. Two of the members of the association, Steingrimur Jonsson, director of the electric works, and Thorkell Thorkelsson, director of the Weather Office, were entrusted with the supervision of these operations.

At a distance of about 2 miles to the northeast of the town there is a small valley with hot springs called *Wash Springs*, Fig. 1, so named because of the custom of the Reykjavik housewives taking their household linen there for washing in the hot water. The name of the town—Reykjavik-Steam-Bay—is said to be derived from the cloud of steam which is continually rising from the springs in calm weather. The water in these springs has a temperature of about 190 F and the rate of flow is about 2.8 gal per second.

Wells Drilled

It was decided to drill wells in the hot springs area of Reykjavik-Steam-Bay and the boring of the first hole was begun in the immediate vicinity of the Wash Springs. At first the progress was slow, for not only were the operators unaccustomed to the work, but the drilling equipment was defective. For a while, the temperature of the ground increased very rapidly and at a depth of 19 ft it had mounted to 180 F. After that the temperature remained about 176 F until a depth of about 34.8 ft was reached, at which depth it began to fall. At a depth of about 59 ft the temperature of the water was 131 F, and as no water came out of the hole when this depth had been reached, the auger was shifted and a new hole drilled at a short distance from the first one.

The work began to progress more satisfactorily, for not only had the operators now acquired some skill, but the drilling machine had also been improved. The temperature did not rise as rapidly as in the first hole. When a shaft of about 28 ft had been sunk, the temperature was only 104 F, but at a depth of 34.4 ft it mounted suddenly to 186 F and hot water *welled up* at the rate of 0.2 gal per second. Figs. 2 and 3 show water spouting forth from bore holes. When boring was continued, the temperature fell to 185 F and remained between 176 F and 185 F until the shaft had reached a depth of 80 ft. It then rose abruptly to 198 F and

FIG. 3—HOT WATER FLOWING OUT OF A BORE HOLE

simultaneously the hot water flow increased to 0.26 gal per second and gradually kept increasing from 83 ft down to 126 ft. The flow had then attained a volume of 0.4 gal per second, the temperature registered being 198 F. When the shaft was closed up the pressure head was equivalent to about 11.5 ft of water. When boring was continued, the temperature soon fell to 181 F and remained so until a depth of 223 ft was reached. At a depth of 200 ft, however, the water supply increased by about 0.18 gal per second and again at 223 ft by 0.66 gal per second. Simultaneously the temperature rose to 200 F and the water that *welled out* was about 199 F. The pressure also increased.

The volume of water increased rapidly and at a depth of 256 ft the rate of flow was 2.64 gal per second. Immediately after the shaft was closed there was a rapid increase in the pressure to a static head of 14.8 ft. The pressure then increased gradually to 32.8 ft. After a shaft of 262 ft had been sunk there was no increase in the volume of water and boring of that shaft was discontinued.

The water supply in the Wash Spring was measured from time to time, but the new shaft did not appear to affect the spring. However, the water in the spring increased when the shaft was closed up, which indicated that the water which came into the shaft at a depth of from 230 to 260 ft had penetrated the upper strata, probably at a depth of about 33 ft, and had flowed into the spring. When the water had been flowing out of shaft No. 2 for a few weeks, the volume had increased to approximately 3.2 gal per second.

The auger was then shifted again and shaft No. 3 was sunk about 130 ft from shaft No. 2. This shaft was drilled to a depth of 460 ft, where water at a temperature of about 194 F was encountered. Shaft No. 4 was then sunk in a hillock where a hot spring had obviously *welled up* some time previous. No water was found at this point, but the temperature registered at a depth of 148 ft was 153 F.

The drilling equipment was again installed in the vicinity of shaft No. 2 where water had been obtained, and a new shaft, No. 5 was sunk to a depth of 761 ft. At this depth the temperature was 177 F. This shaft was closely connected with shaft No. 2 and could be made to spout to a height of approximately 30 ft by temporarily closing shaft No. 2, and then reopening it.

Subsequently, four additional shafts were sunk in different parts of the hot area, but they all proved to be closely connected with shaft No. 2, which gave the richest supply of water. The auger was then taken about 330 ft farther into the valley, where a shaft of 658 ft was sunk. This produced water having a temperature of about 200 F at the rate of 2.9 gal per second, but at the same time it was found that the flow of the other holes bored decreased.

When the flow from the various shafts had become adjusted, it was ascertained that the volume had increased from 2.8 gal per second, which was the original output of the Wash Spring, to 6.1 gal per second. The result of the borings had thus increased the flow to the extent of 3.3 gal per second.

Other Hot Areas

Other hot areas being considered for the heating of Reykjavik are Reykir in Mosfell Parish, Mount Hengill and Reykjanes. Reykir is about 10.5 miles from Reykjavik. This section abounds in hot springs, although the temperature of the water from most of them does not exceed 176 F. Borings would presumably produce hotter water, but as yet no experiments have been made. Mount Hengill is an extinct volcano, about 25 miles to the east of Reykjavik. The subterranean heat is enormous, but it is principally manifested in the form of steam, water not being abundant at this high altitude. The springs, or outlets are, moreover, inconveniently situated to suit the purpose, being mainly on the eastern slope of the mountain, that is, the one farthest from Reykjavik. Reykjanes is a large peninsula forming the southern boundaries of the Faxafloi Bay. Practically speaking, the whole peninsula is an unbroken stretch of lava and presents an extraordinary sight to those who are not accustomed to that form of landscape.

At the farthest point of the peninsula are numerous hot springs—some of them spouting ones—and steam outlets. Undoubtedly there is in this locality a boundless store of subterranean heat not far below the surface, for earthquakes are a regular occurrence. These are usually slight tremblings, however, in fact so slight as to be unnoticeable in Reykjavik, which seems to indicate that they are due to the formation of subterranean steam. This section is about 50 miles from Reykjavik.

These are the hot areas nearest to Reykjavik and consequently are most likely to be used for the purpose of heating the town. Mount Hengill and Reykjanes are indeed situated at considerable distances, and it is not likely that these sources of heat will be used until the town has increased considerably in size. Yet the fact should not be overlooked that in the operating expense of such a system the loss of heat in the conduits is not of great importance, since the cost of obtaining heat at the point of use is very small. The pipe transmission losses for extreme distances would, of course, appreciably affect the delivery temperature.

Heat Supply from the Wash Spring

The Reykjavik authorities have decided to bring the Wash Spring hot water supply into the town. Part of the work on this project has already been completed. The following is a brief description of this scheme:

A pumping station has been erected near the old Wash Spring beside which a tank has been installed for the storage of the water from the different shafts. The pumping plant has been sunk into the ground below the level of the tank to allow the water from the tank to flow to the pumps without any suction. The plant is fitted with three centrifugal pumps, two of which have a capacity of 6.6 gal per second and the third one, about 4 gal per second.

These pumps are driven by electric motors, and the water is pumped into the town through 7-in. steel pipes, which are seamless and connected by welded joints. The pipes are insulated with cork, around which an 0.8-in. thick cover of concrete is cast. This is in turn asphalted and wrapped in jute, and finally in feltpaper. (See Figs. 4, 5, 6 and 7.) At intervals of 165 ft, the pipes are fitted with expansion joints permitting such movement of the pipes as may be produced by changing temperature.

FIG. 4—COVERING A SUPPLY PIPE

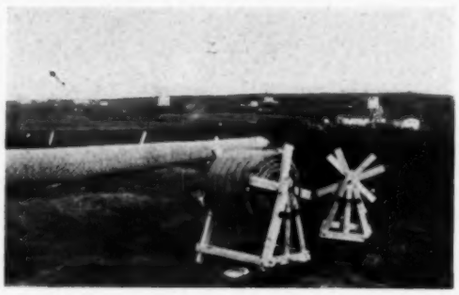


FIG. 5—CORK INSULATION APPLIED TO PIPE

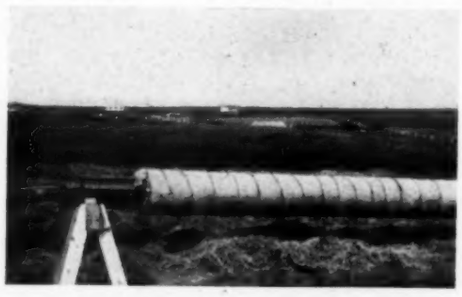


FIG. 6—PIPE COVERED WITH JUTE

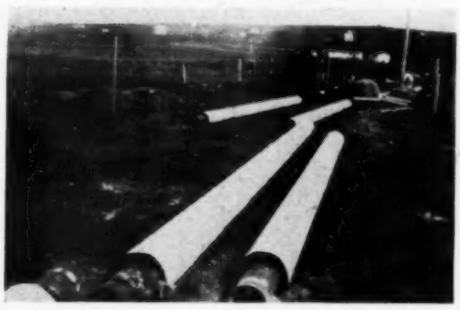


FIG. 7—PIPE WITH FINAL COVERING OF FELT PAPER APPLIED

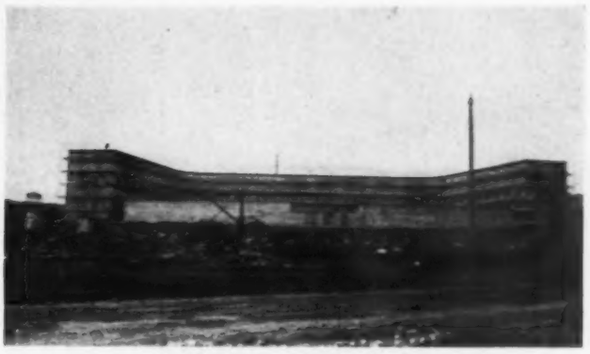


FIG. 8—THE PUBLIC SCHOOL

A pressure regulator is installed in Reykjavik at the terminus of the main supply pipe. This pressure regulator controls the operation of the electric pumps so as to maintain a uniform pressure in the main supply pipe. Pressure equalizing devices are also installed in the supply lines of the buildings.

This system is intended only for the heating of three buildings at present in the course of construction, namely, the National Hospital, a school and an enclosed swimming pool. It is probable that in the Spring of

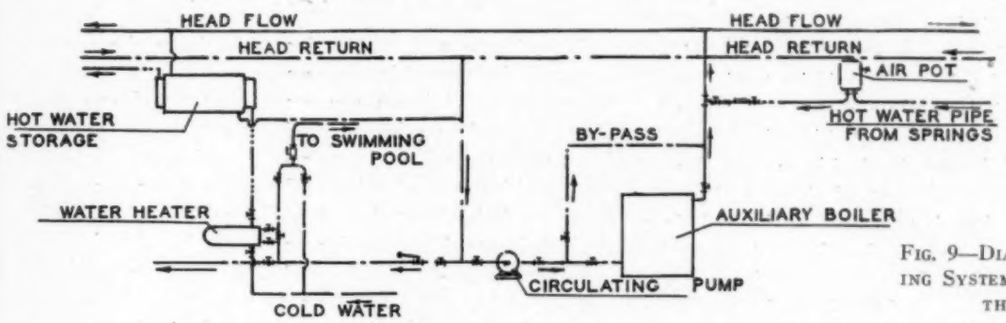


FIG. 9—DIAGRAM SHOWING THE PIPING SYSTEM IN THE BOILER ROOM OF THE PUBLIC SCHOOL

1931 a tank will be erected in the town in which the surplus hot water may be stored during the night. This will greatly enhance the effective capacity of the system, which then should suffice for heating most of the public buildings in the town. On the basis of a temperature leaving the radiators of about 105 F, the system should supply approximately 320,000,000 Btu per 24 hours.

Fig. 8 shows the new public school building which has been heated by means of this system since the early part of November, 1930, and which has a maximum calculated heat loss of 3,080,000 Btu per hour. At present the bore holes are not being used and the hot water is being obtained only from the old Wash Spring. The temperature of the water leaving the spring when the installation was completed was about 183 F, and when it arrived at the school building it was about 178 F, the distance being about 8,850 ft. The water was pumped at the rate of about 2.1 gal per second.

Fig. 9 shows the layout of the piping system in the boiler room of the public school. The flow main of the system is fed directly by the supply pipe from the Wash Spring. After the water has circulated through the system it enters a heater through a check valve where it is heated and then flows into a swimming pool which is located on the ground floor of the building. From the swimming pool it flows to the sewer.

FIG. 10—NATIONAL HOSPITAL

An auxiliary boiler together with a circulating pump has been provided for emergency purposes as shown in the figure.

Fig. 10 shows the National Hospital which, as previously stated, will also be heated by the water from these springs. In general, the piping arrangement for heating these buildings is similar to any hot water installation. The radiators, however, are somewhat larger on account of the lower mean temperature used.

These installations constitute the first steps toward heating the entire town of Reykjavik by means of the hot springs. It is intended to make further investigations of the more distant hot areas and eventually to utilize the abundant supply of hot water available in some of these outlying districts.

Accelerated Slacking Test for Coal

An accelerated laboratory method for testing slacking characteristics of coals has been developed at the Pittsburgh Experiment Station of the United States Bureau of Mines, Department of Commerce, and a large number of low-rank coals tested. The method of test should be of value in predicting the slacking tendencies of different coals. Lignite and subbituminous coals have a pronounced tendency to disintegrate or slack when alternately dried and wetted by exposure to the weather. The more readily a coal slacks the greater is its tendency to ignite spontaneously and the more care must be taken in its shipment and storage. The subbituminous coals tested showed a wide difference in slacking properties.

A study of the moisture content of these coals with the slacking characteristics showed that coals with less than 10 per cent moisture should give little or no slacking trouble; coals with 10 to 20 per cent moisture may slack considerably; and coals with 20 to 30 per cent moisture will slack excessively.

A comparison of the rank of the various coals tested, as measured by their ultimate analyses, with their slacking tendencies show in general a gradual increase of slacking with decrease of rank from high-rank bituminous coal to lignite.

Making Gas and Coke in a Miniature Plant

New methods for determining the composition and quality of coal with a view to improvement in its utilization are constantly being developed by the United States Bureau of Mines at its Pittsburgh, Pa., Experiment Station. One of the most recent developments is a method for determining the amount and quality of carbonization products obtainable from a given coal—that is, the method is designed to compare the carbonizing properties of coals. The apparatus in which this test is made is, in effect, a small coke and gas plant, but arranged for much more accurate control of carbonizing conditions and recovery of products than is possible in a large plant. The charge of coal used is 75 to 90 pounds. This is heated in a welded metal retort charged into an electric furnace whose temperature can be kept constant automatically, and all the products, including coke, gas, ammonia, tar and water are measured and analyzed. The quantities of products yielded in a test, of course, vary with the coal and the carbonizing temperature maintained, but as much as 60 lb of coke, 500 cu ft of gas, and a half-gallon of tar with other products in proportion, are usually obtained. These quantities are sufficient for exhaustive analysis and testing.

Float-and-Sink Method of Control Being Adopted in Many Alabama Coal Washing Plants

In order to maintain a closer check on the performance of their washing plants, a number of coal mine operators in Alabama are now using the float-and-sink method for the testing of washery products according to information obtained in connection with the cooperative coal washing investigations of the Southern Experiment Station of the United States Bureau of Mines and the University of Alabama, Tuscaloosa, Ala.

The advantages of this method can not be emphasized too strongly. The float-and-sink test can be made by the washery man in the space of a few minutes at any time during the day's run. In the procedure, a solution of the proper specific gravity is used for separating samples of the washery products into clean coal and refuse. The washery man who is familiar with the characteristics of his coal knows the specific gravity at which the line must be drawn between washed coal and refuse, and the solution to be used for the float-and-sink tests must be of this specific gravity. The procedure requires a suitable container for solution, the necessary apparatus for separating the float product from the sink product, and a scale for weighing the products. It is customary to screen out the fines from the samples before making the float-and-sink separation as the fines do not separate readily and besides add to the difficulty of keeping the solution clean.

The tests as made by the washery man are not, as a rule, carried out with laboratory precision but the results are obtained quickly, and they give a fair approximation of the ash content of the washed coal. In addition to the rapidity and facility with which the results can be obtained, this method has another important advantage over control by chemical analyses alone, in that a positive separation is obtained between material that should be in the washed coal and material that should be in the refuse, giving the washery man a basis for figuring the amount of clean coal being lost in the refuse and the amount of refuse that enters the washed coal.

PROGRAM

37th Annual Meeting

American Society of Heating and Ventilating Engineers

William Penn Hotel January 26-29, 1931 Pittsburgh, Pa.

SCHEDULE OF EVENTS

JANUARY 26

Monday —A.M.
9:00—Registration (William Penn Hotel).
10:00—Council Meeting.

TECHNICAL PROGRAM

FIRST SESSION, MONDAY, JANUARY 26

2:00—Greeting.
Response—Pres. L. A. Harding.
Report of Council.
Report of Secretary.
Progress of Heating and Ventilating during the Past Quarter Century by R. P. Bolton.
Developments in Heating and Ventilation during 1930, by S. R. Lewis.
Heat Emission from the Surfaces of Cast Iron and Copper Cylinders Heated with Low Pressure Steam, by A. C. Willard and A. P. Kratz.
Heating Effect of Radiators, by R. V. Frost.
Committee on Code for Testing and Rating Concealed Gravity Type Radiation, by R. N. Trane, *Chairman*.
Report of Tellers.

SECOND SESSION, TUESDAY, JANUARY 27

A.M.
9:30—Report of Publication Committee—Prof. G. L. Larson.
Report of Guide Publication Committee—D. S. Boyden.
Development of the Ventilation System of the Holland Tunnel, by A. C. Davis.
Noise Reduction in Ventilating Units, by Warren Ewald.
Noise and Ventilation, by G. T. Stanton.
Some Studies on the Absorption of Noise in Ventilating Ducts, by G. L. Larson and R. F. Norris.
Report of Membership Committee—John D. Cassell.
Report of Increase of Membership—C. W. Farrar.

THIRD SESSION, TUESDAY, JANUARY 27

P.M.
2:00—Report of Finance Committee—F. C. McIntosh.
Air Conditioning as Applied to Furniture, Fixtures and Other Interior Woodwork, by D. R. Brewster.
Air Conditioning in the Bakery, by W. L. Fleisher.
Air Conditioning for Railway Cars, by A. H. Candee.
Committee on Oil Burning Devices by L. E. Seeley, *Chairman*.

FOURTH SESSION, WEDNESDAY, JANUARY 28

A.M.
9:30—Report of Research Committee—Prof. F. B. Rowley, *Chairman*.
Report of the Research Director—F. C. Houghten.
Air Leakage through Various Forms of Building Construction, by F. C. Houghten, Carl Gutberlet and C. A. Herbert.
Capacity of Return Mains for Steam and Vapor Heating Systems, by F. C. Houghten and Carl Gutberlet.
Welded Piping for Building Heating Systems, by F. G. Outcalt.
Air Pollution from the Engineers' Standpoint, by H. B. Meller.
Smoke and Dust Abatement, by M. D. Engle.

WEDNESDAY, JANUARY 28

P.M.
2:00—Inspection Trip—Research Laboratory, Bureau of Mines and Carnegie Tech.

FIFTH SESSION, THURSDAY, JANUARY 29

A.M.
9:30—Spectral Distribution of the Energy Radiated from Metallic Surfaces at High Temperatures, by G. R. Greenslade.
Insulating Effect of Successive Air Spaces Bounded by Bright Metallic Surfaces, by L. W. Schad.
Wind Velocity Gradients Near a Surface, and Their Relation to Film Conductance, by F. C. Houghten and Paul McDermott.

SIXTH SESSION, THURSDAY, JANUARY 29

P.M.
2:00—Utilization of Hot Springs for Heating in Iceland, by Ben Gröndal.
Off-Peak System of Electric Heating, by Elliott Harrington.
Heating with Exhaust Steam, by Perry West.
Installation of Officers.
Announcement of Rules of Award for F. P. Anderson Medal.
Resolutions.
Adjournment.
4:30—Council Meeting (Organization of 1931 Council).

ENTERTAINMENT PROGRAM

JANUARY 26

Monday —P.M.
12:30—Luncheon for Council and Authors.
2:00—Inspection Tour and Tea for Ladies at Kaufman's Department Store.
9:00—A Night in Pirate Hall (William Penn Hotel).
Westinghouse Program.
Music, Cards, Dancing.

JANUARY 27

Tuesday —A.M.
8:00—Breakfast Meeting—Committee on Research.
P.M.
1:00—Luncheon and Bridge for Ladies (William Penn Hotel).
6:30—Annual Dinner Past Presidents.
Dinner for Wives of Past Presidents.
8:00—Miniature Championship Golf Tournament for Miniature Research Cup (William Penn Miniature Course)

JANUARY 28

Wednesday—A.M.
10:45—Sightseeing trip for Ladies.
Lunch at Heinz.
P.M.
1:00—Meeting of Nominating Committee, Pittsburgh Athletic Club.
1:15—Luncheon for Members, Pittsburgh Athletic Club.
7:30—Annual Banquet and Dance—Urban Room (William Penn Hotel).

JANUARY 29

Thursday —
Visit to KDKA Broadcasting Station, William Penn Hotel.
Inspection of Industrial Plants.

Of Interest to Members

Midwest Power Show in Chicago February 10 to 14, 1931

The 5th Midwest Power Engineering Conference and the 4th National Fuels Meeting of the *American Society of Mechanical Engineers* will meet at the Stevens Hotel, Chicago, February 10 to 14, where they will be addressed by well known authorities on the subjects involved.

In connection with these meetings the Midwest Engineering Exposition will present a cross section of the latest developments in power machinery and appliances at the Coliseum.

In spite of the business depression, G. E. Pfisterer, managing director of the Exposition, anticipates an attendance comparing favorably with past records. Communications from the engineering field indicate unusually keen interest due to the realization of a need for a revaluation of many factors in power economics to meet present and future conditions.

The Power Show, the Power Conference and the Fuels Meeting will present a rare educational opportunity to the young as well as the older engineers, supplying a common meeting ground for valuable contacts and interchange of views and assimilation of the newest developments in the field of engineering.

An unusually large number of exhibits of heating, ventilating and refrigerating equipment is assured for the exposition, thus giving the visting engineers and others interested in the power machinery world an opportunity to gain an insight into these branches of the industry which are being developed along new lines.

The fields of generation, utilization and distribution of power will also be given prominence. The engineers will have an opportunity to study their specific problems, including fuel oil burners and refractories, pumps, pumping accessories, water treating equipment, chemicals, transmission of supplies and equipment, boilers and boiler problems, motors, tools and metal working equipment and numerous other machines and appliances.

The Engineering Conference will be in session from February 10 to 12, while the Fuels Meetings will be held from the 11 to the 13.

W. H. Carrier, First Vice-President of the American Society of Heating and Ventilating Engineers and President of the Carrier-York Corp., Newark, N. J., will deliver a paper on New Application of Refrigeration in Air Conditioning, which he will present at the Refrigeration and Ventilation Session at 8:00 P. M., Tuesday, February 10.

Some of the other topics to be discussed are as follows: The Economics of Fuel Utilization; New Processes of Dehydrating Low Grade Coal; Symposium of Small Stokers by T. A. Marsh; Utilization of Anthracite Coal by C. A. Connell; The Combustibility of Solid Non-Coking Fuels by R. V. Frost, G. S. Scott and assisted by H. G. Turner; Conversion of Coal Fired Boilers and Furnaces to Gas Firing by W. D. Edwards; and The Fly Ash Problem by H. N. Bubar. All of these will be presented at the Wednesday session, February 11.

Among the interesting subjects to be given particular attention at the Thursday session are: Developments in Pulverized Fuel Firing by H. Kreisinger; Effect of Fineness of Pulverization on Boiler Efficiencies by E. H. Tenney; Radiation in Boiler Furnaces by N. Artsay and Lighting of Pulverized Fuel Fired Furnaces by S. C. Page.

Changes in Character of Mid West Coals and Stoker Performances by E. L. McDonald and a General Discussion Meeting on Smoke Abatement and Air Pollution which will be given by Messrs. Whitlock and Hutchinson will be among the interesting papers at the session on Friday, February 13.

Oil Burner Show

Unprecedented interest in the eighth annual Oil Burner Show to be held at Philadelphia in April is being displayed by manufacturers of oil burning equipment and accessories, according to the *American Oil Burner Association.* Shortly after December 1, 104 out of 123 booths had been taken and many of the remaining booths had been placed on option. The 104 spaces contracted for at that time had been taken by 63 exhibitors.

It was stated that plans were under consideration for adding more booths to the total space available to accommodate those who may be unable to secure space otherwise.

The innovation last year in opening the show to the general public as well as dealers and manufacturers is believed to have quickened interest in the event. Manufacturers are planning to bring out their latest improvements and introduce many new models at the Philadelphia show.

W. P. Yant Appointed Supervising Engineer

The appointment of W. P. Yant, East Sparta, Ohio, as supervising engineer of the Pittsburgh Experiment Station of the U. S. Bureau of Mines, Department of Commerce, has been announced by Scott Turner, Director of the Bureau of Mines. Mr. Yant succeeds G. St. J. Perrott, who has accepted a position on the research staff of the A. O. Smith Corp., Milwaukee, Wis.

Mr. Yant was graduated from the College of Wooster, Wooster, Ohio, in 1918. Immediately following graduation he joined the staff of the Chemical Warfare Service at American University, Washington, D. C. He joined the gas laboratory staff of the U. S. Bureau of Mines in 1920, and in 1923 was appointed chemist-in-charge of the Bureau's gas laboratory. In 1925 he became supervising chemist of the health laboratory section, which comprises the gas laboratory; gas mask and respirator laboratory; pathological, physiological, and biochemical laboratory and the stream pollution laboratory of the Bureau of Mines Experiment Station. In this capacity he has been in direct charge of research and service work of the Bureau which pertains to the examination of mine and tunnel atmospheres from the viewpoint of mine ventilation, control of mine fires, and investigation of explosions.

Mr. Yant is the author of many publications of the Bureau of Mines and of articles which have appeared in technical journals. He has been granted two patents, one for a simple method for quantitatively determining the carbon monoxide in the blood of supposed victims of poisoning and which is widely used in hospitals and by health officials; the other for the use of helium oxygen mixtures rather than normal air in diving and caisson operations at high pressure.

Mr. Yant is a member of the *American Chemical Society, American Public Health Association, American Association for the Advancement of Science,* and the *Coal Mining Institute of America.*

Simplification Program

The Division of Simplified Practice of the Bureau of Standards, Department of Commerce, has announced that the standing committee of the industry for Simplified Practice Recommendation No. 8-29, Range Boilers and Expansion Tanks, has reaffirmed the existing schedule, without change, for another year.

CANDIDATES FOR MEMBERSHIP

The Constitution of the Society, as now amended, requires the following mode of procedure in voting on applicants for membership in the Society. All applications for membership are to be sent to the Secretary and the name of applicants and their references shall be printed in the next issue of the Journal of the Society or sent to the members in other approved manner as ordered by the Council. When replies are received from references, the Candidate's application shall be submitted to and acted upon by the Membership Committee as soon as possible.

When the Membership Committee has acted favorably upon a Candidate's application and assigned his grade, the Council shall vote upon the election of the proposed Candidate for membership by letter ballot. During the past month 30 applications for membership have been received and the names of these men and their sponsors are published in the following list.

Members are requested to scrutinize the list with care. The Membership Committee, and in turn the Council, urge the members to assume their share of the responsibility of receiving these candidates into membership by advising the Secretary promptly of any whose eligibility for membership is in any way questioned.

All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote.

Unless objection is made by some members by February 14, 1931, these candidates will be balloted upon by the Council. Those elected to membership will be notified by the Secretary immediately after election.

CANDIDATES	REFERENCES	
	Proposers	*Seconders*
Bowes, Frank Richard, Sales Repr., Herman Nelson Corp., Boston, Mass.	H. W. Nelson F. T. Tyler	E. H. Beling L. F. Nordine
Carey, Thomas M., Sales Repr., Herman Nelson Corp., Defiance, Ohio.	H. W. Nelson F. T. Tyler	M. G. Munson E. H. Beling
Cole, Edwin Q., Sales Engr., The Herman Nelson Corp., Springfield, Mass.	H. W. Nelson F. T. Tyler	R. H. Nelson E. H. Beling
Dockeray, Fayette, Sales Repr., The Herman Nelson Corp., Kingston, Pa.	H. W. Nelson F. T. Tyler	M. G. Munson E. H. Beling
Daly, Robert E., Asst. to Pres., American Radiator Co., New York, N. Y.	R. B. Howell C. H. Flink	W. R. Zuhlke O. O. Oaks
Fritzberg, Hilding L., Student Engr., Carrier Engrg. Corp., Newark, N. J.	W. G. Hillen L. L. Lewis	H. L. Janet Herman Worsham
Heath, William R., Asst. Chief Engr., Buffalo Forge Co., Buffalo, N. Y.	Joseph Davis C. A. Booth	E. E. Johnson A. A. Criqui
Heslip, John C., Chief Engr., National Air Control Co., Kansas City, Mo.	H. C. Henrici E. K. Campbell	H. J. Nottberg F. F. Dodds
Hexamer, Harry D., Manager of Mfr., Excelso Products Corp., Buffalo, N. Y.	Joseph Davis L. A. Cundall	L. N. Castin C. H. Love
Johnson, Louis Henry, Owner, L. H. Johnson Co., Minneapolis, Minn.	Albert Buenger A. M. Wagner	E. J. Burns E. F. Jones
Killeen, Edmund Francis, Sales Repr., The Herman Nelson Corp., Duluth, Minn.	H. W. Nelson F. T. Tyler	M. G. Munson E. H. Beling
Lamb, Edward A., Owner, E. A. Lamb Plbg. & Heating Co., Minneapolis, Minn. (*Reinstatement*)	Albert Buenger A. J. Huch	J. B. Harris W. F. Uhl
Leonard, Joseph Hamilton, Mfr's. Repr., J. T. Leonard Co., Winnipeg, Manitoba, Canada.	H. W. Nelson F. T. Tyler	M. G. Munson E. H. Beling
Lindsey, William Judson, Salesman, The Herman Nelson Corp., Peoria, Ill.	H. W. Nelson F. T. Tyler	M. G. Munson E. H. Beling
Magney, Gottlieb Renatus, President, Magney & Tusler, Inc., Minneapolis, Minn.	Albert Buenger A. J. Huch	L. C. Hanson H. J. Sperzel
McCulloch, Laurence, Manager, Richardson & Boynton Co., Buffalo, N. Y.	Joseph Davis D. J. Mahoney	F. H. Burke L. N. Castin
Miller, Edgar S., Branch Mgr., Pneumatic Process Corp., Kansas City, Kans.	W. H. Carrier E. K. Campbell	W. A. Russell E. K. Campbell, Jr.
Morrison, Chester B., Vice-Pres. & Genl. Mgr., York Shipley, Inc., Shanghai, China.	W. E. Heibel L. A. Harding	W. F. Goodnow H. B. Eells

MURRAY, WOODWORTH NORTHEY, Sales Repr., The Herman Nelson Corp., Boston, Mass.	H. W. Nelson F. T. Tyler	E. H. Beling L. F. Nordine
O'HAVER, HUBERT MAURICE, American Blower Corp., Los Angeles, Calif.	C. S. Anderson H. B. Keeling	Leo Hungerford A. H. Berg
OLSTAD, MARTIN HUGO, Asst. Chief Engr., Niagara Blower Co., Buffalo, N. Y.	Joseph Davis C. A. Bulkeley	L. N. Castin L. A. Cundall
RACK, EDGAR C., Staff Mgr., Engrg. Dept., Johns-Manville Corp., New York, N. Y.	A. A. Adler F. E. Giesecke	W. G. W. Turno R. H. Heilman
ROOKS, ALFRED WENDELL, Sales Repr., The Herman Nelson Corp., Cincinnati, Ohio.	H. W. Nelson F. T. Tyler	M. G. Munson E. H. Beling
SHELNEY, THOMAS, President, Pierce Blower Corp., Buffalo, N. Y.	Joseph Davis F. H. Burke	O. K. Dyer R. T. Thornton
SPOODIS, ANTHONY, Sales Repr., The Herman Nelson Corp., Moline, Ill.	H. W. Nelson G. E. Otis	E. H. Beling R. H. Nelson
STEPHENSON, GEORGE ARTHUR, Engr., W. E. Shaddock, Buffalo, N. Y.	Joseph Davis F. H. Burke	L. N. Castin O. K. Dyer
TAVANLAR, E. J., Yale Univ., New Haven, Conn.	J. H. Holton D. E. French	D. M. Abel F. W. Arko
THORNTON, WILLIAM BARRY, Branch Engr., Carrier-Lyle Corp., Pittsburgh, Pa.	H. B. Orr H. L. Moore	H. P. Gant R. S. Arnold
WHEELER, CHARLES A., Sales Repr., The Herman Nelson Corp., Des Moines, Iowa.	H. W. Nelson F. T. Tyler	M. G. Munson E. H. Beling
WYMAN, DWIGHT M., Sales Repr., The Herman Nelson Corp., Barrington, R. I.	H. W. Nelson F. T. Tyler	M. G. Munson E. H. Beling

Candidates Elected

In past issues of the Journal of the Society the names of the following men were listed as Candidates for Membership. The membership grade of each Candidate has been assigned by the Membership Committee and balloted upon by the Council. We are now instructed by the Council to post herewith, as required by Art. II, Sec. VIII, of the By-Laws, the following list of candidates elected:

MEMBERS

BAILEY, GEORGE B., Thermal Engrg. Co., Boston, Mass.

BERNSTROM, BERT, Engr., Lakeside Co., Hermansville, Mich.

BRIGHAM, FREDERICK HUBBARD, Sales Engr., Gilbert Howe Gleason, West Medford, Mass.

BROWN, WILLIAM ARTHUR, Consulting Engr., 205 East 42nd St., New York, N. Y.

BRUST, OTTO, Chief Constr. Engr., Carrier Lufttechnische Gesellschaft, Stuttgart, Germany.

BUNKER, FRANK J., Chief Engr., Master Fan Corp., Los Angeles, Calif.

GILLIAM, OLIVER FULGHAM, York Heating & Ventg. Corp., Chicago, Ill. (*Advancement*)

HILL, FRED MILROY, Consulting & Supervising Engr., Fred M. Hill, Los Angeles, Calif.

HUMPHREYS, JAMES, McQuay Radiator Corp., New York, N. Y.

JOHNSON, CARL E., Sterling Elec. Motors, Inc., Los Angeles, Calif.

KNIBB, ALFRED E., Heating Engr., Vagg Wilson Co., Ltd., Regina, Saskatchewan, Canada.

KNOX, JAMES ROSS, Asst. Heating Engr., Lord & Burnham Co., Irvington, N. Y.

MAHONEY, DAVID JOHN, Branch Mgr., Johnson Service Co., Buffalo, N. Y. (*Advancement*)

ORR, GEORGE MILTON, President, G. M. Orr & Co., Minneapolis, Minn.

OSMUNDSEN, HARRY B., Vice-Pres. & Sales Mgr., McQuay Radiator Co., New York, N. Y.

SALISBURY, WILLIAM CONYNE, Sales Engr., American Radiator Co., Detroit, Mich.

STEELE, ALFRED N., Gen. Sales Mgr., Trane Co., La Crosse, Wis.

TYSON, PERRY W., Heating & Ventg. Draftsman, W. M. Anderson, Philadelphia, Pa.

ZINK, DAVID D., Branch Sales Engr., American Radiator Co., Kansas City, Mo.

ASSOCIATES

COOK, CHAUNCEY JEWETT, Puro & Cook, Syracuse, N. Y.

GILLESPIE, J. D., President, Gillespie & Tinkham, Los Angeles, Calif.

HARRIS, HAROLD RUSSELL, Sales Engr., Manufacturers' Agent, Minneapolis, Minn.

JUNIORS

DELANCEY, RALPH W., Sales Mgr., Designing Engr., Real-Oil-Heat Burner Co., Winona, Minn.

HERMAN, J., JR., Estimator, J. Herman Co., Los Angeles, Calif.

NESBITT, JOHN J., JR., John J. Nesbitt, Inc., Philadelphia, Pa.

ROSKE, FREDRICK MELVIN, Asst. Mgr., The H. Smith Co., Fair Haven, N. J.

STUDENTS

GABELMAN, HAROLD D., Student, Carnegie Institute of Technology, Pittsburgh, Pa.

SCHOENOFF, ALFRED EMIL, Student, Carnegie Institute of Technology, Pittsburgh, Pa.

Heating · Piping and Air Conditioning EDITORIALS

Canadian Research

President Hoover said recently: "Our scientists and inventors are among our most priceless national possessions. There is no sum that the world cannot afford to pay these men who have that originality of mind, that devotion and industry to carry scientific thought forward in steps and strides until it spreads to the comfort of every home. The world today needs more support for research. It needs more laboratories."

And so it is a pleasure to observe and commend the plans that are going forward for the establishment at Ottawa, Canada, of the National Research Laboratories. Canada with her great agricultural, hydroelectric, animal husbandry, fishing, mining, lumber and manufacturing interests, with her thirteen college schools of applied science, is establishing organized research on an extended scale through these laboratories.

Work will be conducted along two distinct lines. First, research will be conducted in the general interest of the public, funds to be supplied by the *National Research Council*. Secondly, the Council will undertake work along the lines of the Mellon Institute, where an organization that wishes to have work done for itself can get it done, the information to be handed back to it for its own individual benefit.

Among the various subjects to be studied at the Canadian laboratories are heat transmission through walls, heat transmission through building material, nocturnal radiation, utilization of natural gas, determination of the moisture content in grains in order to improve the conditions for grain in storage, as well as many other problems in biology, chemistry, physics and engineering. Canada is to be congratulated upon this enterprise.

One Make of Equipment?

One of the problems that confronts operating engineers and maintenance employes is the advisability of maintaining a standard in the different kinds of equipment that they select and use in their plants.

As for an illustration, by using the same make of globe valves, gate valves, reducing valves, steam traps, thermostatic traps, radiators, faucets, ball cocks, water heaters and other equipment, there is no doubt that it would be easier and more convenient to keep a complete stock of the necessary repair parts, attachments, diaphragms, washers and other requirements on hand. The maintenance employes will become familiar with the repairs, adjustments and care of the plant equipment, which all will agree is a desirable feature, especially in the larger plants where the work is diversified and there is a large amount of machinery and equipment.

Another view of this situation is that there is a "splendid opportunity," when these suggestions are followed, of getting behind the times. Manufacturing conditions are changing and improving at a rapid rate. The plant engineer may be in a position to make repairs and replacements promptly and yet be losing ground in over-all efficiency. Equipment that is the best on the market today may, in a short time, be superseded by new and better devices.

It would be interesting to know exactly what the majority of engineers do in this matter; is the purchase of different types and makes of equipment encouraged or discouraged?

Heating Costs

In many buildings the proportion of the cost of heating to the total cost of operation is necessarily high, in other types of buildings it is low. A bulletin from the University of the State of New York says that more than 25 per cent of the total cost of operation of the public schools of that state was for fuel alone.

The bulletin shows that in New York, at least, the cost of heating in recent years has been upward and that there is a surprising difference in the amount of fuel used in similar latitudes and in like structures.

There are many factors contributing to variations in heating cost. But which is the major factor and what the relation is between these factors is not very well understood. Some engineers maintain that the greatest fault in the manipulation of school heating plants is lack of uniformity in temperature. Sometimes the rooms are underheated and sometimes overheated. One engineer maintains that the largest factor contributing to heating cost may be explained by the differences in air filtration of different buildings. Another engineer who has had wide experience believes the difference lies largely in the operating engineer and his method of firing.

It would seem that a thorough study of the cost of

operating heating systems, where it seems to be high in comparison with other buildings, would be in order. Often a small investment in new equipment will repay large returns in decreased operating charges.

Degrees of Air Conditioning

"Advertisements of hotels and theaters stating that 'a new air conditioning and cooling system has just been installed for so-many thousand dollars' frequently makes it a little difficult to sell the owner of a small business structure or a residence on the advisability of providing air conditioning," said an engineer. "Too frequently, the general public feels that air conditioning and all its benefits are out of reach, financially, for the comparatively small building."

As in every other field, air conditioning systems may be had in degrees of completeness. The system that is economically successful for a large office building, a hotel or a theater (where it serves thousands of people) may be entirely too complete to be justified, in all cases, for a home or a small office. We must educate the public to realize that this is true; and that some degree of air conditioning is infinitely better than none at all. No one is going to resign himself to walking just because he cannot afford a Rolls-Royce; perhaps more applicable still, no one refuses to spend the money for an automobile because a railroad train, carrying hundreds of passengers, costs more to purchase than he can afford.

Air conditioning systems will soon be the rule for every building; the day will be hastened when the public realizes that their cost is commensurate with the service they perform.

Chicago Power Show

One of the outstanding events on the calendar of the heating, piping and air conditioning engineer for February is the Midwest Power Conference, to be held in Chicago from the tenth to the fourteenth. The National Fuels Meeting of the American Society of Mechanical Engineers is to be held in conjunction with the conference; in addition, an exposition will serve to demonstrate the latest equipment in the power, piping and related fields.

According to information which has been released, there will be an unusually complete exhibit of air conditioning and heating equipment this year. New developments in the refrigerating industry, which is said by many to be in a state of particularly rapid progress at the present time, will be explained and demonstrated.

It is essential these days that we keep in close touch with the developments in equipment and thought in our field; the Midwest Conference should aid materially in making engineering information more available.

Know the Reason

We all recall the story of Henry Jones, who spent thirty years at a railroad junction, tapping each wheel of every train that stopped there. One day a vice-president of the road, interested in the faithful service of the employe, stopped off to ask him about his work. "Just why do you tap each wheel?" he asked. "Danged if I know, boss," was the reply.

There are other men like Henry Jones in the world today, even if they have not as long a service record and occasionally some are maintenance employes.

An investigation by officials and supervisors of this class of work will show that often there are employes who go about their work in a routine manner, with very little thoughts as to the "reason why" and little effort to adopt progressive methods.

Employes engaged in maintenance work should be very familiar with their equipment, know how to correct the faults, and should know why.

Use of History Cards

It is very easy to discuss, theoretically, the determination of the economic life of equipment, but it is quite another matter to be charged with the responsibility of assembling the necessary data for and carrying forward an actual replacement program. The making of replacements and the installation of new acquisitions on the basis of opinion unsubstantiated by detailed cost analysis is by no means uncommon.

Even though an establishment may not be equipped with a thoroughly organized cost accounting system there are certain simple records of experience which are of inestimable value to the engineer. An example of the value of a mere record of the cost of repairs to individual pieces of equipment is afforded by a case which arose in a foundry. A system of history cards was instituted in this shop and revealed that the annual cost of repairs to the sand blast equipment was half again as much as the installed cost of new and more modern equipment. The individual items of repairs were not of sufficient magnitude as to direct attention to the uneconomic status of the equipment. Such is the nature of the twins "Wear" and "Tear."

History cards also serve a valuable purpose by revealing repeat repairs which in some cases may be entirely eliminated by a minor and inexpensive change in design. An example of such a history card service is afforded by a case where a repeat repair on a crane wind brake coming to the attention of the maintenance agency through the history card system precipitated an investigation of the brake. A slight change in design eliminated further expense from this source. There is much of value in a system where cost of maintenance of heating, piping and air conditioning equipment is recorded.

Some Reports on Research

Investigation at Cleveland of Gas Line Joints—A Combination Ventilation-Silencer

A. G. A. Joint Research

An exhaustive investigation on repairing leaky pipe joints and methods of pipe joint construction is being carried on by the *American Gas Association* at its laboratory in Cleveland, Ohio. The association's pipe joint research committee, headed by O. S. Hagerman of the American Light & Traction Co., Chicago, has been at work for several years collecting data on pipe joint failures, prevailing practices in joint repair, installation standards, and the relative importance of stresses from underground temperature changes, ground settlement, and other causes.

R. M. CONNER

Gas Leakage Expensive

"The problem of gas leakage is of considerable importance to the industry," states R. M. Conner, director of the *A. G. A.* testing laboratory. "Statistics of the association show that the total output of the manufactured gas industry during 1929 was about five hundred and eighty billion cubic feet. It has been estimated that at least 5 per cent of this amount, or close to thirty billion cubic feet of gas, was lost in that year through leakage in the distribution system. This represents an annual loss of fuel which has a sales value, if taken at an average figure of one dollar per thousand cubic feet, of almost thirty million dollars. If through improved methods of new joint construction and more effective means of repairing old joints, the loss from this source can be substantially reduced, a tremendous saving will result each year. Large industrial plants, with considerable gas piping, should also be able to show savings by careful maintenance of the piping.

"The actual work in research and testing of pipe joints began at the laboratory on July 1, 1929, under the immediate supervision of K. R. Knapp, distribution engineer, formerly with the United Gas Improvement Co.

"An initial program outlined by the pipe joint committee has been followed in conducting the investigation. This was confined at the start to bell and spigot joints. It included as its main features a study of old joints removed from service to determine the best means of repairing them, the testing of numerous new joint combinations prepared in various ways, together with other investigations collateral to this work.

Universities Co-operate

"It was necessary to make extensive use of testing machines of rather large capacity to carry out a number of the physical tests required. Suitable arrangements were accordingly made to utilize the equipment of university laboratories for this purpose. Such a plan has been found to produce excellent results. Most of the testing has been carried on at Case School of Applied Science in Cleveland. Some of the heavier work, however, has been done at the University of Pennsylvania in Philadelphia.

Old Joints Secured

"The development of effective means for repairing old joints was first undertaken, due to the recognized importance of this subject. To obtain the samples needed, a number of joints, mostly in the 4 in. and 6 in. sizes, were secured from gas companies who removed them from service in various sections of the United States. Various types of material had been used for these joints, which rendered them particularly valuable in this investigation.

Tested for Leakage

"The joints received were tested for leakage. Only a few, however, proved tight. A test procedure was devised to determine the amount of bending or deflection to which the specimens could be subjected before leakage started. This test was designed to reproduce the effects of ground settlement. It consisted in mounting the specimen, which was usually about six feet in length, with the ends closed on two supports spaced five feet apart. Loading was applied through a testing machine upon the side of the bell, which was located midway of the supports. The load and deflection was noted at which leakage occurred with a pressure of 10 pounds maintained on the joint. One-half inch was selected as the maximum deflection to be given. If no leakage took place, the test was repeated up to a maximum of four deflections, the joint being rotated one-half turn between each set of loadings.

Methods of Repairing Joints

"Before attempting to repair old joints, a summary was made of the practices recommended by a large number of distribution engineers throughout the country. The methods most generally recommended were as follows:

1. Cut out the old joint material and remake joint.
2. Re-caulk.
3. Apply leak clamps.

"In conducting an investigation of the first method recommended, joints made up in several different ways were tested to determine the effectiveness of such repair. The tightness of such joints was determined by applying an air pressure of 50 pounds. The joints were then subjected to a deflection test similar to the one previously discussed. It was found possible to make tight joints by following the various methods involving the cutting out of the old material and remaking the joint. However, in most cases when the deflection test was applied, leakage

was found to occur comparatively early. Accordingly, it did not seem that this general method of repair represented the solution to the problem.

Use of Leak Clamps

"A rather extensive investigation was also made into the use of leak clamps for repairing old joints. The results obtained thus far indicate that this is one of the most effective methods for accomplishing the desired results. Different types of gaskets were used in connection with this method of repair and the results showed that the composition of the gasket, as well as its width, have an appreciable effect upon the results obtained. The use of gasket cement in the application of leak clamps was also found to add considerably to their effectiveness.

Effect of Temperature Changes Studied

"A large amount of testing and research work has also been devoted to various types and methods of new joint construction. In this case, a test method was worked out to reproduce, as far as possible, the effects of seasonal contraction and expansion of joints caused by variations in ground temperatures. A plan was developed by which a sample could be placed in a testing machine and alternately pulled apart and pushed together, each tension and compression being the equivalent of one year's temperature change on the joint. The test finally adopted consists in subjecting the test specimen to a maximum of 45 alternate tensions and compressions, or reversals, under loads gradually increasing to that corresponding to a change in temperature of 60 F.

"Reversals were started at an air pressure of 10 lb. In case the test joint remained tight at the end of 40 reversals, the pressure was increased in 10-lb. increments to 50 lb. with a single reversal at each pressure. If leakage occurred, the pressure was reduced to 1 lb. and the test continued to the end or until leakage again occurred. In case of leakage, the pressure was reduced to 10 inches (water column) and the test continued to the end or until leakage occurred at this pressure. In this way it was possible to determine the relative performance of various types of joints under different pressure conditions.

"A considerable number of joints of different types have been tested including cement, cement mixtures, lead, and combinations of rubber rings with both cement and lead. Most of these have been in the 4-in. size. This size was chosen as representative of small pipe to reduce as far as possible the cost of material and permit of easier handling. A number of tests have, however, been made on 6-in. joints as representative of large pipe. While much valuable information has been secured, so much still remains to be done that it is impossible to draw any final conclusions at this time.

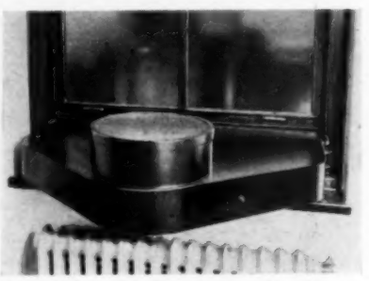
"A number of miscellaneous investigations have also been carried on. Among them may be mentioned a study of the properties of cement as applied to joint making purposes, a determination of the effective depth of caulking of lead, and an investigation of the action of different kinds of gas upon yarn. Considerable work has also been done in an attempt to measure the extent of vibration in underground mains due to modern traffic. The theory has been advanced that such vibration may have a tendency to increase leakage from joints and this investigation is being made to prove or disprove it.

"In addition to these features, new aspects of the problem have continually presented themselves. As an example, arrangements have been made with the *Cast Iron Pipe Research Association* to conduct an extended series of tests of mechanical joints. Broadly speaking, the plans for conducting the various tests follow the same general lines that have been explained previously. Much higher pressures are used, however, and a number of details have been added."

Noise-Silencing Combined with Ventilation

A test installation has just been made by the Hartford National Bank & Trust Co., Hartford, Conn., of a new ventilation-silencer arrangement which is designed to shut out street noises without sealed-shut windows and to produce complete air change within the room.

The installation is made in the director's room. Four out of six windows are equipped with the new silencers,



TEST INSTALLATION OF A VENTILATOR—SILENCER

two set to draw in fresh air, and two for air exhaust. The sound deadening effect is the result of the special type of air passageway provided which allows free flow of gases but contrives to trap the sound waves and keep them out.

The window ventilating fans can be set either as intakes or exhausts. The apparatus is simple. A silencer is mounted with a fan for ventilation. The fan fits into a circular box six inches high above the silencer. One lifts the window, locks in the box, closes down the window, connects a cord to some near-by electric outlet, and the installation is done. The motor consumes the same electric power as a lamp bulb. The operating switch thrown one way draws air into the room; reversed, it serves to exhaust air.—*S. P. M.*

Galvanic corrosion or electro-chemical action is a process of electricity generation due to the difference in potential of two different forms of metal or similar substances in a solution.

Roughly, the resulting process is similar to what takes place in a storage battery and results in the ultimate destruction of one of the metals involved. This same principle is made use of in galvanizing iron pipe, in silver plating and in numerous other common commercial processes. In the connection referred to (where cast iron piping was pitted as the result of the generation of electrolytic currents) the process works to the destruction of the pipe. To overcome this form of corrosion it is necessary to set up a means for diverting the flow of current in another direction so that the piping under consideration ceases to be one of the active electrodes of the theoretical galvanic cell.

PRACTICAL PIPING PROBLEMS

Shortening an Inaccessible Pipe Coil. Hydraulic Piping Damaged by Freezing.

by **W. H. WILSON**

Shortening a Steam Pipe Coil

Plant conditions required a change to be made in a pipe coil fifty feet long, which was, for the most part, obstructed by the steel supports of a storage rack, containing heavy steel dies and machine parts.

To shorten this pipe coil by removing the lengths of pipe and connecting the remaining pipes by threading and replacing with screwed joints, would require considerable labor for removing the dies and replacing them.

The work was done in the following manner:

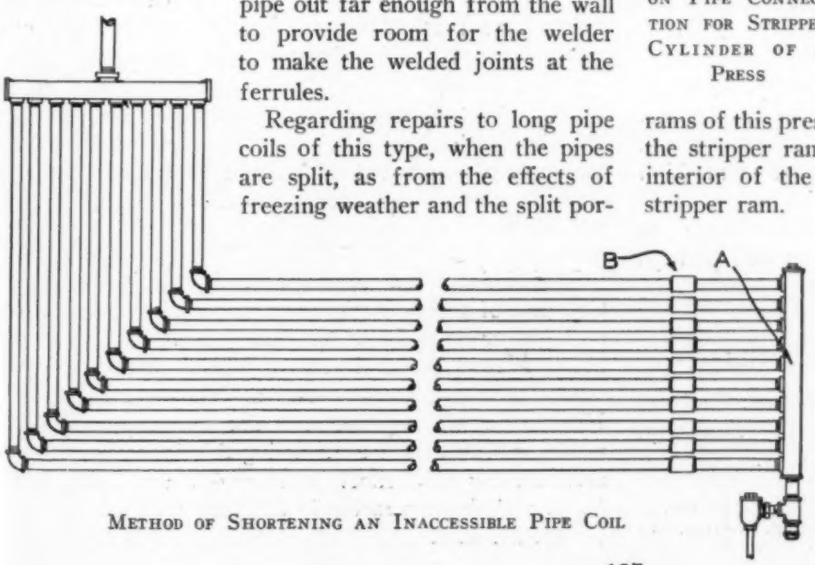
An acetylene cutting torch was used to cut the circulation pipes about 12 inches from the manifold at the return end of the heating coil. The portion of the pipe coil that was to be removed was then cut and the pipes removed, which could be done without interference from the material rack.

In order to weld conveniently the short pipes in the return manifold to the remaining circulation pipes, short pieces of pipe, of a size large enough to slip over the circulation pipes, were used. It is only natural that there would be some slight variation in the length of the circulation pipes when they were cut by the torch and by using the short pieces of the larger size pipes as ferrules this permitted the return manifold to be placed in position and each circulation pipe adjusted itself for length as its time came for welding.

One end of these ferrules was welded before the return manifold was placed in position.

The illustration shows the pipe coil with alterations completed. The return manifold is shown at *A*, the welding ferrules at *B*. The size of the circulation pipes was 2 in. The ferrules were pieces of 2½-in. standard wrought pipe, 4 in. long. It was possible to bring the pipe out far enough from the wall to provide room for the welder to make the welded joints at the ferrules.

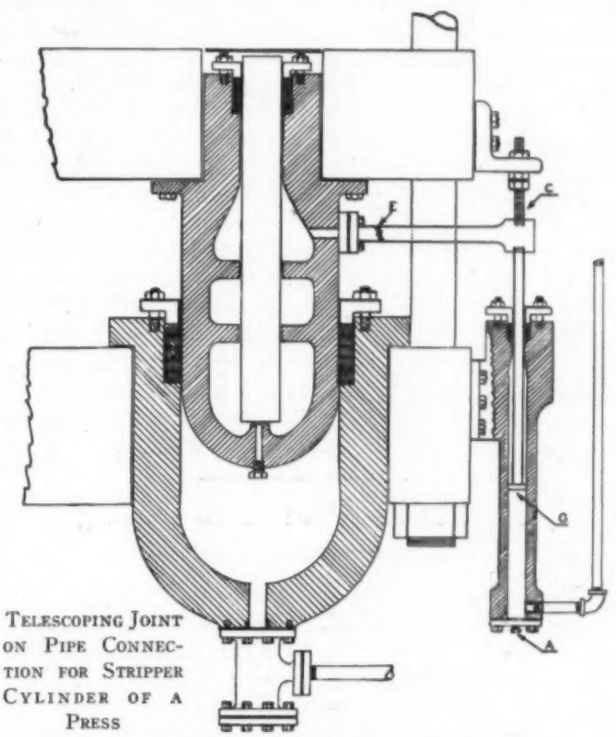
Regarding repairs to long pipe coils of this type, when the pipes are split, as from the effects of freezing weather and the split portion is obstructed or turned toward the wall, it is usually possible to take two pair of pipe tongs and by working them together, turn the pipe into position, convenient for the welder to make the necessary repairs, without removing or replacing the pipe.



METHOD OF SHORTENING AN INACCESSIBLE PIPE COIL

Hydraulic Piping Damaged by Freezing

The illustration shows a telescoping joint on the pipe connection for the stripper or "kick out" cylinder of an up-stroking hydraulic press. All of the cylinders and rams of this press are located in the pit, beneath the press, the stripper ram being inside of the main ram, and the interior of the main ram being the cylinder for the stripper ram.



TELESCOPING JOINT ON PIPE CONNECTION FOR STRIPPER CYLINDER OF A PRESS

As the main ram travels up and down, it is necessary to provide a telescoping joint for the pipe connection from the operating valve to convey the pressure water used for raising the stripper ram and also to allow the water to return through this pipe as it is expelled from the cylinder when the ram makes the downward stroke.

On one occasion, the press was drained and blown out with compressed air, but the workmen failed to

remove the drain plug at the base of the cylinder for the telescoping pipe joint, shown at *A*. The water remaining in this cylinder froze and the strength of freezing water was shown by the pressure exerted on the stud bolt, *C*, which was not tightened securely. This stud bolt, which was used to support the moving pipe, bent out of position and the special cast fitting, shown at *E*, was broken.

The expansion of the freezing water in the lower part of this small cylinder apparently caused an upward strain, which bent the stud bolt and put the strain on the connecting fitting, *E*, which was not in a position or strong enough to raise the moving platen of the press. The lower end of the moving pipe, shown at *G*, was fitted with a guide, which may have helped to make a piston head when the freezing occurred.

Steam forging hammers not in use, but with the steam pressure on, are not liable to be damaged by freezing weather as there is usually enough leakage through the valves to permit steam to pass from the supply pipe and through the hammer into the exhaust pipe, which keeps the cylinder, valve chest and packing boxes above the freezing temperature. When steam is shut off, the hammer should be thoroughly drained and blown out with compressed air. The main cylinder is usually provided with a drip valve at the lower part of the cylinder.

When the hammer cylinder is drained at this point, there will still be some water and moisture which will accumulate in the packing box at the lower end of the cylinder around the piston rod. In this case, the packing box gland bolts should be loosened. Extreme cold weather will cause this wet packing to freeze and expand. If the gland bolts are not loosened, the expansion is liable to cause the gland bolts to break or pull out.

This will apply to packing box gland bolts on hydraulic press cylinders, accumulators and similar machinery. The safest plan is to loosen all of these bolts, if the packing is not removed, preparatory to laying the equipment up in advance of freezing weather.

Helium as Medium in Drying

By Charles S. Mann*

The desirable properties of helium for drying operations are well recognized. The apparatus designed for such drying and shown in the recent article,[1] also would operate satisfactorily. However, this is a batch drying process. Every time material would be removed after drying or charged into the apparatus for drying, a certain amount of the helium would be lost from the system. The oftener the charging or discharging of the material, the larger the loss of helium which, because of the high cost of helium, would make the cost of drying considerable. The most serious criticism, therefore, is the possible high cost of this drying medium and perhaps the cost of regeneration of the silica gel.

Conventions and Expositions

American Society of Mechanical Engineers: National Fuels Meeting, Feb. 10-13; Chicago, Ill. Secretary, Calvin Rice, 33 W. 39th st., New York City.

Midwest Power Engineering Conference: Feb. 10-13; Chicago. Secretary, G. E. Pfisterer, 308 W. Washington st., Chicago.

National Industrial Congress and Exposition, National Management Congress: April 13-18; Cleveland, Ohio. Executive Committee, 819 Citizens Building, Cleveland.

American Oil Burner Association: Convention, April 13-18; Benjamin Franklin Hotel, Philadelphia.

American Welding Society: Annual meeting, April 22-24; New York City. Secretary, M. M. Kelly, 33 W. 39th st., New York City.

Recent Trade Literature

Air Conditioning: B. F. Sturtevant Company, Hyde Park, Boston, Mass.; bulletin describing a new sectional unit which filters, cools, humidifies, or dehumidifies air; particularly recommended for theaters and public buildings. Physical data, resistance to air flow, and performance tables are given; the compactness of a typical job is stressed.

Air Conditioning: Niagara Blower Co., 95 Liberty st., New York City; folder devoted to an air conditioning unit for industrial processes and comfort. Typical applications are shown.

Air Conditioning: The Silica Gel Corporation, Baltimore Trust Building, Baltimore, Md.; fifty-page, well illustrated, book describing silica gel and its many uses. The book is divided into parts—dehydration; air conditioning (industrial and comfort); refrigeration (railroad, truck and commercial); refining; solvent recovery; catalysis; and miscellaneous.

Industrial Electric Heating: Westinghouse Electric & Manufacturing Company, Mansfield Works, Mansfield, Ohio; 100-page catalog of operating data, charts, tables, photographs and specifications of industrial heating equipment. The last part of the publication covers controls.

Unit Heaters: C. A. Dunham Company, 450 E. Ohio st., Chicago; 32-page booklet showing capacities, dimensions, and suggested methods of installation of unit heaters. One section gives electrical motor information; wiring diagrams for manual and automatic control are shown in another. Tubes are joined to the headers by a patented process said to have many advantages.

Non-ferrous Welding: Niagara Blower Co., 95 Liberty st., New York City; two bulletins showing typical work done in welding and fabricating non-ferrous equipment for chemical plants and other corrosion resisting uses.

A Correction

In the advertisement of the Peerless Unit Ventilation Co., Inc., of Bridgeport, Conn., published last month, the architect and engineer of the Floral Park-Bellerose School, Floral Park, L. I., was given as Knappe & Morris, New York; the contractor as Johnson Heating Co., New York. At the request of this company and its advertising agent, we are correcting this information. The architect for this school is Edward Hahn, Hempstead, L. I., and the contractor is the James McCullagh Co., Hicksville, L. I.

*Chief, Division of Chemical Engineering, University of Minnesota.

[1] *Helium as a Circulating Medium in Drying Operations.* Heating, Piping and Air Conditioning, November, 1930, p. 921.